JUN - 5 1934

Vol. 3 JUNE, 1934 No. 5

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The Journal of Thoracic Surgery

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Published Bi-Monthly by
The C. V. Mosby Company, 3523 Pine Blvd., St. Louis, U. S. A.
Entered as Second Class Matter at Post Office at St. Louis, Mo.

The Journal of Thoracic Surgery

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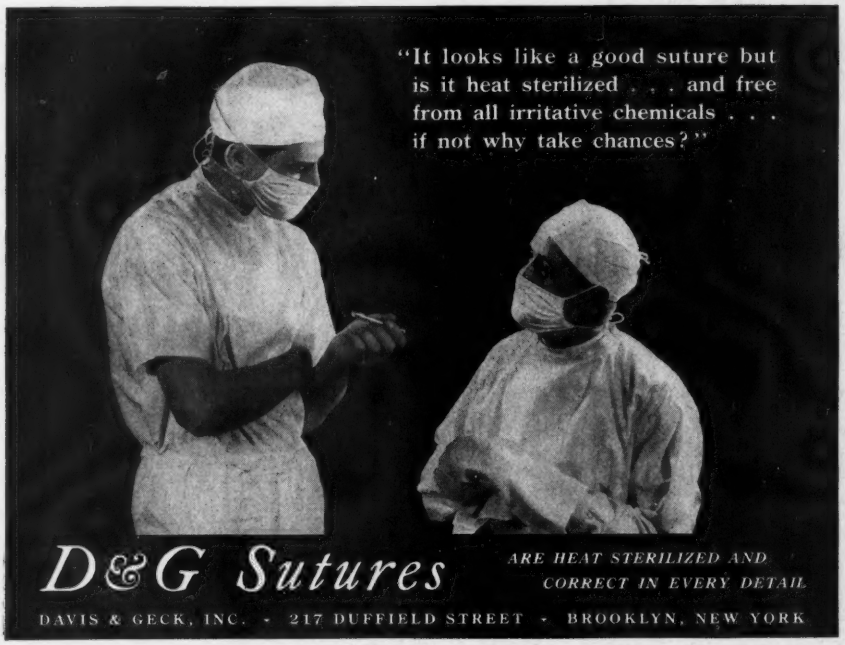
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The Journal of Thoracic Surgery

VOL. 3 JUNE, 1934 NO. 5

Original Communications

170 CASES OF THORACOPLASTY (307 OPERATIONS) FOR PULMONARY TUBERCULOSIS, OPERATED ON FROM 1931 TO 1933

CLINICAL STUDY AND RESULTS*

POL. N. CORYLLOS, M.D.
NEW YORK, N. Y.

THE efficiency of thoracoplasty in the treatment of pulmonary tuberculosis is universally admitted today. A number of important points, however, are still open to discussion. The most essential are: the technic, the postoperative complications and their management, the indications, the immediate and late mortality and the ultimate results.

The object of this paper is to present the results of my personal experience based on 170 thoracoplasty cases (307 operations), operated upon within the last two years (1931-1933). This material came from Seaview Hospital and the tuberculosis division of Metropolitan Hospital of the city of New York, both under the medical direction of Dr. G. G. Ornstein. This center comprises 2,200 beds for tuberculosis and other thoracic cases.

The patients operated upon were first studied thoroughly by the medical staff and special departments—radiographic, nose and throat, cardiac, gastrointestinal, orthopedic and laboratory. They were then presented to the surgical conference where the indications for surgical treatment were discussed by the members of the medical and surgical staffs. After operative treatment the results were appraised again at

*Read before the American Association for Thoracic Surgery in Washington, D. C., May 9, 10 and 11, 1933. (Completed and extended for publication.)

From the Departments of Thoracic Surgery, of Metropolitan and Seaview Hospitals of New York City.

joint conferences and the causes of success or failure analyzed. The important material at our disposal and the active cooperation of a surgically-minded medical staff rendered possible the trial of different procedures and the appreciation of their respective value, advantages and disadvantages. For these reasons, although the total number of my cases is not very large and the time elapsed since operation is still relatively short, the lessons taught by this experience may be of some value to those interested in this subject. An earnest and painstaking effort was made in this work to present the facts as they are. During this period of two years, which I shall call experimental not so much for the procedures used as for the extent of the ground explored, the principal scope was to investigate the indications for operation and the limits of operability of tuberculous patients. Having adopted as a basis for our work the classification of Ornstein, Ulmar and Dittler, we have arrived at fairly definite conclusions upon which our work during the coming years is going to be based.

For a comprehensive exposition of this study, the following plan was adopted. First, I shall give my general impressions of the surgical treatment of pulmonary tuberculosis, especially concerning the respective value and indications for the different surgical procedures; then I shall describe the changes brought about, by accumulated clinical experience and experimental investigation, in my general conceptions and technic. The three components of the technic, that is, preparation, operative procedure, and postoperative care, will be described. The indications for thoracoplasty will be studied next; last, a detailed analysis of the results obtained in these cases and of the morbidity and mortality will be given. No references to the literature will be made.

GENERAL SURVEY OF THE SURGICAL TREATMENT OF PULMONARY TUBERCULOSIS

Before going into my subject I wish briefly to submit a few general ideas on the surgical treatment of pulmonary tuberculosis, based partly on clinical experience and partly on experimental investigation. It is useful, from time to time, to stop our purely analytical treatment of the subject and try to express our actual conceptions as they have been built up. Surgical treatment of pulmonary tuberculosis undergoes swift and profound changes. We are all pioneers in this young branch of surgery, and one cannot afford to be dogmatic. Our conceptions and ideas must change and do change as we learn more about the surgical physiology of the endothoracic organs and their functions, more especially as we begin to understand better the hitherto totally neglected pathologic physiology of the tuberculous lung.

It seems that thus far we have placed the different methods of collapse of the lung on the same plane without a definite perspective as

to their relative significance and value. Personally, I believe that an outstanding place should be given to two procedures—pneumothorax and thoracoplasty. The others are either accessories of one of these methods (as oleothorax, closed or open pneumolysis are of pneumothorax; or as apicolysis and operations of the type of Coffey-Lawers, Bernou-Casper, Proust, Mallet-Guy and Desjacques, etc., are of thoracoplasty) or procedures of limited value and indications such as phrenicectomy or multiple intercostal neurectomy.

Thus the question of choice of method in the surgical treatment of pulmonary tuberculosis can be limited, at least in the great majority of cases, to a choice between pneumothorax and thoracoplasty. Thus far it has been considered that pneumothorax should be applied first, and where this has failed thoracoplasty has been advised.

Is this conception correct? I believe not. So long as we have had no other methods of treatment for tuberculosis than bed rest or pneumothorax and so long as thoracoplasty presented a prohibitive mortality this reasoning was justified. This view is no longer valid, especially when we consider lesions strictly limited to one or even both apices. The perfection in technic of the present apical thoracoplasty in which only three ribs are resected at each time but in their entirety, produces a physiologic amputation of the upper half of the upper lobe; its negligible morbidity and mortality and the striking results thus far obtained with it in cases in which pneumothorax had been impossible, force us, I believe, to reconsider our ideas on the subject. As will later be shown the most brilliant results in my cases were obtained by this procedure and especially in cases with strictly apical lesions; in going over the literature one finds that all authors without exception have had a similar experience.

On the other hand, without underestimating the valuable aid thus far given by pneumothorax in the treatment of this disease, we should admit that pneumothorax has a number of serious shortcomings. First, surgically speaking, pneumothorax cannot be considered a perfectly sound procedure. In fact, in thoracic surgery we always strive to close the pleural cavity as rapidly as possible, having good reasons to consider its patency as a potential menace and a source of complications. Indiscriminate and routine use of pneumothorax, prolonging it for years, even in cases in which complete collapse was not obtained, the rapidly increasing use and abuse of this method by many practitioners, the idea that it represents an easy and harmless procedure, the increasing number of cases with positive sputum receiving ambulatory pneumothorax treatment and the long duration of the treatment, constitute, I believe, a humane, financial and social problem which deserves more serious consideration than has thus far been given it. Only experienced phthisiologists know the difficulties of good management of pneumothorax and its limitations. Unfortu-

nately they are not the only ones to use this method so that very often valuable time is lost by indiscriminate continuation of pneumothorax allowing limited apical lesions, easily curable by effective collapse, to spread and become unmanageable. It is appalling how often, in going over previous radiograms of actually desperate cases, we find that there was a time when apical thoracoplasty could certainly have turned the scales in favor of the patient.

It is, after all, a variation of the old question of pneumothorax versus bed rest now brought up as the problem of apical thoracoplasty versus pneumothorax. Let us hope that this time the decision will not take so long to be made as in the previous instance. I am not unaware of the fact that men with limited surgical experience do not hesitate to formulate such sweeping statements as that "thoracoplasty never cured a tuberculous cavity"; it is interesting to note that they are the same men who only a few years ago expressed in equally dogmatic terms a similar opinion against pneumothorax (Fishberg, Wiener and Fishberg). These statements would be of little importance were they not to bring influence to bear on physicians who are already ultraconservative by instinct, habit or prejudice.

On the other hand, it is generally known that in 80 per cent of all cases of pulmonary tuberculosis the lesions are located in the apex; that small cavities with elastic walls sometimes close spontaneously and, as a rule, easily with effective collapse treatment; that the persistence of a cavity is a serious condition regardless of its actual size; that so long as a cavity remains open and the sputum positive the patient is almost certainly doomed; that the terms "arrested disease" or "improved patient" are meaningless so long as the sputum remains positive and last but not least that the large thick-walled cavities develop from the small thin-walled variety.

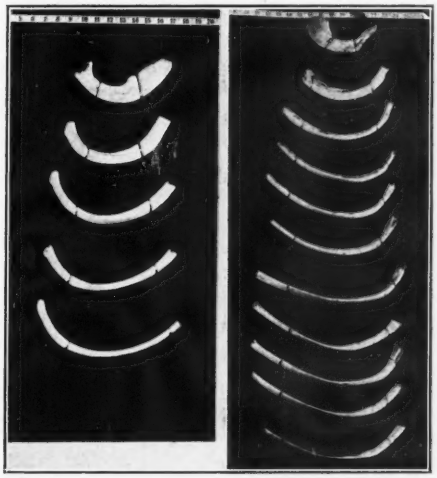
On the basis of these factors I have arrived at the following considerations: In cases in which a reasonably long bed rest period has proved that we are dealing with real cavities and when these cavities are located strictly in the apex, the treatment of choice should be neither pneumothorax nor phrenicectomy nor apicolysis but apical thoracoplasty. No other procedure is likely to give such a high percentage of cures (see Table IX) and in such a short time. The same conclusions hold for bilateral cases provided that they are strictly confined to the apices. On the contrary, with more extensive lesions, pneumothorax, aided when necessary by pneumolysis, is a better procedure and should be tried first and continued, when successful, because of the still existing high mortality of total thoracoplasty and the frequently resulting deformities. It is understood, however, that when pneumothorax does not succeed in collapsing a cavity it should be discontinued after a reasonable time and a thoracoplasty advised, without unnecessary delay. I feel that this change of our present way

of reasoning would benefit our patients and that it represents a more rational solution of the problems involved in this disease than the indiscriminate and routine use of bed rest, pneumothorax or phrenicectomy.

An analytical study of 170 cases of thoracoplasty will show the evidence upon which this conception was based and developed.

CHANGES IN TECHNIC

The technic followed in the cases reported in this work has undergone important changes. Preoperative care, operative procedure and postoperative management have not been the same for the first as for the last cases. In this respect I can divide my cases into three groups.



A. *B.*

Fig. 1.—*A*, First-stage thoracoplasty, with resection of 5 ribs as performed in first and second groups of patients. *B*, Eleven ribs resected in two stages, on patients of the same groups. For 3 rib thoracoplasties (third group) see Fig. 19.

The first 84 cases were operated on with the procedure of paravertebral extrapleural thoracoplasty as described by Sauerbruch, with only slight changes. General, local and even high spinal anesthesia was used. A vertical paravertebral incision was made very slightly curved outward at its lower end. The scapula was forcibly retracted and the mass of the paravertebral muscle dissected free from the ribs. Contrary to Sauerbruch and Archibald, in all cases except one, the upper ribs were resected first. In 28 cases preliminary phrenicectomy with scalenotomy was performed. The number of ribs resected at the first stage in this group was generally five to six and only in advanced cases or when operative expediency was indicated by the patient's condition was a smaller number of ribs resected. The lengths

of resected segments of ribs were greater than those given by Sauerbruch. The average lengths of the first ribs in the first 84 cases were: 8.5 cm. for the first rib, 10.5 cm. for the second and 16 cm. for the third. (Fig. 1.)

The average total length of the resected ribs was 190 cm.

This technic was slightly modified in the second group (31 cases) in accordance with the procedure described by Proust, Rolland and Maurer. The transverse apophyses were visualized by liberation of the paravertebral muscles from the plane of the ribs and forcibly retracted then toward the middle line. The transversocostal joints were opened with the chisel and hammer and the tips of the transverse apophyses sectioned; in this way the rib could be cut very close to its head. In seven cases it was possible completely to disarticulate the first rib.

In the first group of patients endotracheal gas oxygen ether anesthesia was used. The rational, technical details and results obtained with this method of anesthesia have already been published extensively in this JOURNAL.

In the second and third groups avertin was given rectally as a basal anesthesia and supplemented by gas oxygen inhalation; in only a very limited number of cases slight amounts of ether were added.

In the third group endotracheal anesthesia combined with bronchial suction was reserved for these patients who expectorated more than 15 c.c. in twenty-four hours. The number of postoperative pulmonary complications was almost nil in the two last groups.

The operative technic was radically modified in the last group. The one used in the first group was perhaps more anatomical but had two inconveniences—a greater loss of blood and especially a longer operating time. The average time of an upper stage thoracoplasty operation in which five to seven ribs were resected was from thirty-five to fifty minutes. Postoperative shock was more severe; mediastinal flutter and respiratory embarrassment were more frequent, and anoxemia was more pronounced. Transfusions in the first two groups were required in 65 per cent of cases.

Gradually the technic was modified with the constant preoccupation to lessen the postoperative shock. It was found that resection of only three ribs at the first stage fulfilled the requirements by decreasing blood loss, lessening the dangers of mediastinal flutter, of respiratory embarrassment and of anoxemia and by shortening the duration of the operation. Preoperative and postoperative determinations of CO_2 and O_2 content of the arterial and venous blood and for a period of ten days after operation have shown that anoxemia was decreased by this procedure. I think that this must be attributed to the smaller portion of the lung brought to collapse. As I have shown elsewhere,

sudden collapse of a larger portion of one lung produces an immediate impairment in its ventilation without cutting off the blood circulating in the alveolar capillaries; circulation is markedly impaired only when the air entrapped in the alveoli is absorbed and atelectasis is produced. In the meantime blood circulating through unaerated channels goes to the left heart insufficiently oxygenated and pollutes the arterial blood of the systemic circulation. Mucus draining from the collapsed lung during operation into the healthy lung may block small or even larger size bronchi, thus further increasing anoxemia. The operative procedure actually used, by avoiding this extensive collapse and the formation of large unaerated areas in the lung, prevents the sudden increase of the chronic anoxemia already present in tuberculous patients.

The postoperative care was also modified. Greater attention was given to the metabolism of sodium chloride. A thorough investigation on this important point is now being carried on in Seaview Hospital. The results so far obtained with postoperative administration of hypertonic sodium chloride solution have been very significant, as will be shown below.

These are, briefly stated, the main changes in the management of thoracoplasties brought about during the past two years. In the following paragraphs I shall describe in detail the preoperative preparation, operative procedure and postoperative care as carried out in the last group of patients.

OPERATIVE TECHNIC

1. Preoperative Care.—Unfortunately we do not as yet possess any reliable physiologic test, comparable to the functional kidney test, by which one can determine the resistance of patients. Study of the changes in O_2 and CO_2 content in arterial and venous blood and the alveolar air, before and after a standard exercise, and of the heart output calculated by Fick's formula offers a basis for the elaboration of such a test. This question is now under investigation. In a general way, however, the degree of acceleration of respiration and pulse can give useful indications. It would be advisable to postpone thoracoplasty on patients who, after going up and down ten steps, show an increase in respiration rate to over 35 and a pulse rate to over 125.

A hemoglobin content, as measured by O_2 capacity of the blood, which is lower than 65 per cent, has been considered as a contraindication to operation. When, however, this could not be corrected by liver treatment or small transfusions but all other conditions were satisfactory, I have not hesitated to operate. Patients withstood the three rib upper thoracoplasty very well, even with a hemoglobin as low as 60 per cent. The importance of the blood picture, white cell shift and sedimentation test are now being studied by Dr. Goldberg

at Seaview Hospital. Specimens of blood are examined before operation and then weekly until the patient is discharged from the surgical wards. From the results thus far obtained we can draw the following conclusions. The most reliable single prognostic element of the blood constituents seems to be the total number of lymphocytes in a cubic millimeter of blood. Generally their number varies inversely as the sedimentation rate, but they bear no steady relation to the total number of white cells. Increase in the number of lymphocytes indicates a favorable course and prognosis.

As an example I shall give a case which is demonstrative of the whole group.

M. J., male, white, aged twenty-three years. Onset of the disease August, 1930. Caseous pneumonic lesions in the upper and mid portions of the left lung with large thick-walled cavities. Pneumothorax from August, 1932, unsuccessful; received only 5 refills.

Blood picture August 8, 1933:

Hemoglobin 96 per cent; R.B.C. 4,960,000; W.B.C. 11,500; nonsegmented cells 460, 4 per cent; polymorphonuclears 6,720, 68 per cent; eosinophiles, none; lymphocytes 1,725, 15 per cent; monocytes 1,495, 13 per cent.

Sedimentation:

15 m. 0 mm.
30 m. 1 mm.
45 m. 3 mm.

First stage thoracoplasty August 4, 1933. First, second, and third ribs (10, 14 and 16.5 cm.). Blood picture August 11 (one week postoperative):

Hemoglobin 78 per cent; R.B.C. 4,120,000; W.B.C. 9,250.

Sedimentation:

15 m. 18 mm.
30 m. 45 mm.
45 m. 70 mm. Lymphocytes 1,480, 15 per cent.

Suddenly on the tenth postoperative day (August 14) the patient had a chill and the temperature rose to 104° and then gradually fell on the sixteenth day. Wound infection. *Staphlococcus albus* found in the smears.

Blood picture: August 15, 1933.

Hemoglobin 81 per cent; R.B.C. 4,260,000; W.B.C. 14,500.

Sedimentation:

15 m. 9 mm.
30 m. 32 mm.
45 m. 52 mm. Lymphocytes 455, 3 per cent.

September 11, 1933. Wound still open. General condition good. No infection.

Blood picture:

Hemoglobin 73 per cent; R.B.C. 4,090,000; W.B.C. 9,000.

Sedimentation:

15 m. 14 mm.
30 m. 22 mm.
45 m. 36 mm. Lymphocytes 1,710, 19 per cent.

September 12, 1933. Second stage thoracoplasty (fourth, fifth and sixth ribs, 20, 21 and 22 cm.).

Blood picture: September 19, 1933.
Hemoglobin 58 per cent, R.B.C. 3,860,000; W.B.C. 17,550.

Sedimentation:

15 m. 50 mm.
30 m. 95 mm.
45 m. 114 mm. Lymphocytes 2,808, 16 per cent.

Blood picture: September 24, 1933.
Hemoglobin 80 per cent; R.B.C. 4,130,000; W.B.C. 12,200.

Sedimentation:

15 m. 2 mm.
30 m. 8 mm.
45 m. 14 mm. Lymphocytes 4,026, 33 per cent.

By that time the sputum had become negative, the wound had healed and the general condition was excellent.

In this case although hemoglobin, red cells and sedimentation tests were unfavorable, a rise of the lymphocyte count was an encouraging sign.

Great care was also taken to have the patient cough and expectorate for two days preceding the operation. When the amount of sputum exceeded 30 c.c. in twenty-four hours, postural drainage was used. Careful mouth washes and tooth inspection are of importance.

Much attention has been given to the preparation of the skin before operation. The technic used for bone operation was strictly carried out. This precaution has considerably decreased the percentage of postoperative infection, as will be shown later.

Amytal or luminal, grains iii, was given the evening preceding the operation, and this dose was repeated four hours before operation; not only for psychic reasons but also as an antidote for cocaine which was used for the introduction of the endotracheal catheter. No morphine or scopolamine was used before operation.

The amount of sputum expectorated by the patient before and after operation was recorded on the chart with the variations in the number of tubercle bacilli found in it, expressed in Gaffky numbers, from 1 to 10. Interesting lessons were taught by this study, still being carried on at Seaview Hospital by Dr. Nadell. (Fig. 2.)

2. Anesthesia.—In the 80 patients of the last two groups, anesthesia was carried out in the following way: In all patients expectorating over 15 c.c. of sputum in the twenty-four hours my endotracheal catheter was used (Fig. 3).

The glottis and larynx of the patient were anesthetized by instillations of 0.5 c.c. of 10 per cent cocaine into the glottis with a laryngeal syringe by indirect laryngoscopy. The catheter is then introduced, and the pharynx and oral cavity are tightly packed in order to prevent any aspiration into the lung of the septic contents of the mouth and pharynx.

Cough reflex caused by the introduction of the endotracheal tube is easily controlled with a few drops of 10 per cent cocaine solution injected into

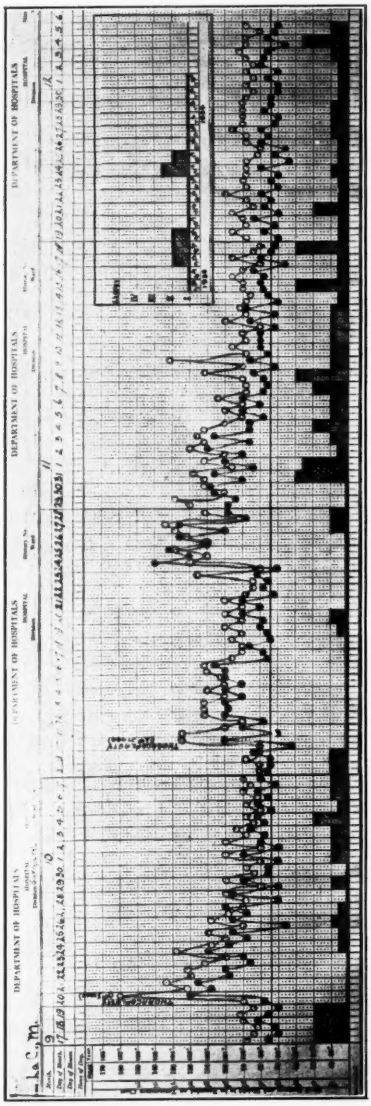


Fig. 2.—Chart showing temperature, pulse and sputum variations following thoracoplasty. Results of sputum examinations shown in Gaffky units are noted in the right upper angle of the chart. Expectoration is interrupted following each stage of thoracoplasty. Eleven days following second stage expectoration was impaired; an elevation of temperature with signs of lobar consolidation followed which was resolved within seven days; at that time expectoration appeared again. Sputum became negative for tuberculosis twelve days after second stage.

the bronchi through the tube. A semirigid rubber catheter connected with a suction apparatus is introduced from time to time into the endotracheal tube and the bronchial contents are thoroughly aspirated. Usually

from 2 to 30 c.c. are removed. The exudate is sent to the laboratory for routine examination for pneumococcus.

Avertin is then given rectally, 80 mg. per kilogram body weight. The endotracheal tube is connected with the McKesson recording anesthesia apparatus and gas oxygen is given to the patient. Since the use of avertin, ether has been almost completely eliminated. During the operation the bronchial content is aspirated at more or less frequent intervals according to the need. Thus far this method of anesthesia has given me complete satisfaction. I have noticed no untoward effects of avertin except occasionally a slight period of restlessness after operation.

Respiratory accidents during operation have been nil since the patency of the respiratory ways has been secured by the endotracheal tube.

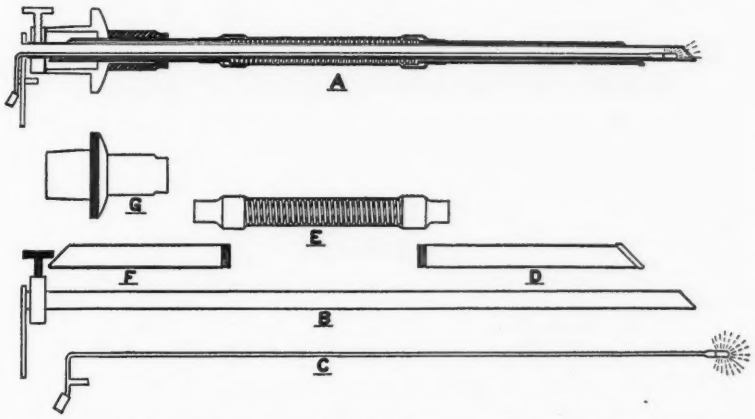


Fig. 3.—Coryllos-McKesson endotracheal catheter. The inhaler (*A*) may be introduced by direct vision through the hollow tube (*B*) provided with electric lamp carrier. (*C*) After introduction through the larynx and into the trachea the rigid tube is withdrawn. The flexible noncollapsible spring section (*E*) covered with Penrose rubber tubing, permits flexion without kinking. The proximal end of the tube (*F*) affords air-tight attachment of the mouth prop (*G*) while adjusting itself to the proper position at the teeth. Mouth prop is also provided, at the proximal end, with suitable connection for attachment to anesthetic apparatus. The instrument may be introduced also with the aid of a laryngoscope (Fig. 5) as described in the text.

Cardiopulmonary postoperative complications, rather frequent in the first group as was shown elsewhere,[3] were greatly diminished in the second and almost completely eliminated in the third group.

I am aware of the objection that endotracheal anesthesia somewhat complicates the operative procedure. I am satisfied, however, that its advantages warrant this complication. On the other hand, the technic of introduction of the catheter is a simple one, easy to acquire, and I believe that the house staff of a thoracic surgical service should be instructed in the manipulation of laryngoscope and endotracheal tubes in particular and in bronchoscopic technic in general.

Toward the end of the operation oxygen carbon dioxide (10 per cent) is administered for from five to ten minutes.

In the graph made by the recording anesthesia apparatus of McKesson the following are indicated: the tidal air and respiratory tracing, the percentages of gas-O_2 used, the blood pressures, and the timing of the different operative acts. Useful information was gathered by the study of these records.[3]

3. Operative Procedure.—Position of the Patient. The patient is placed on the table in lateral decubitus and firmly held within this position. The chest rests on soft pillows in order to avoid undue pres-

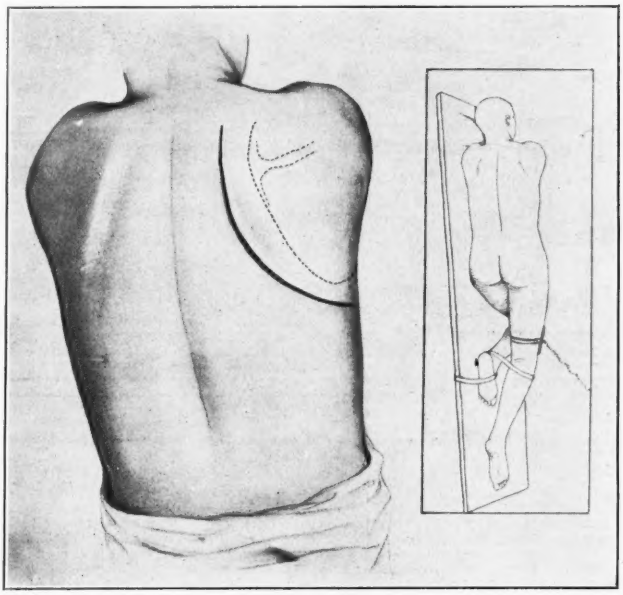


Fig. 4.—Incision for upper stage thoracoplasty, begins at the level of the second dorsal spinal process, runs parallel to the spinal border of the scapula and terminates on the posterior axillary line.

Inclusion: Position of patient on the operative table. Electrode for hemostasis by thermocoagulation attached on upper leg.

sure on it. The enclosure of Fig. 4 shows how the feet and legs are attached to the table. A four-inch width of adhesive (not shown in the illustration) is attached to one side of the table, passes over the buttocks and is fixed on the other side of the table, assuring immobilization of the patient so that undue pressure upon the chest is avoided and change of position of the patient during operation is prevented.

Diathermy. The indifferent electrode of a diathermy machine is fixed to the thigh of the patient for hemostasis by thermocoagulation. In six

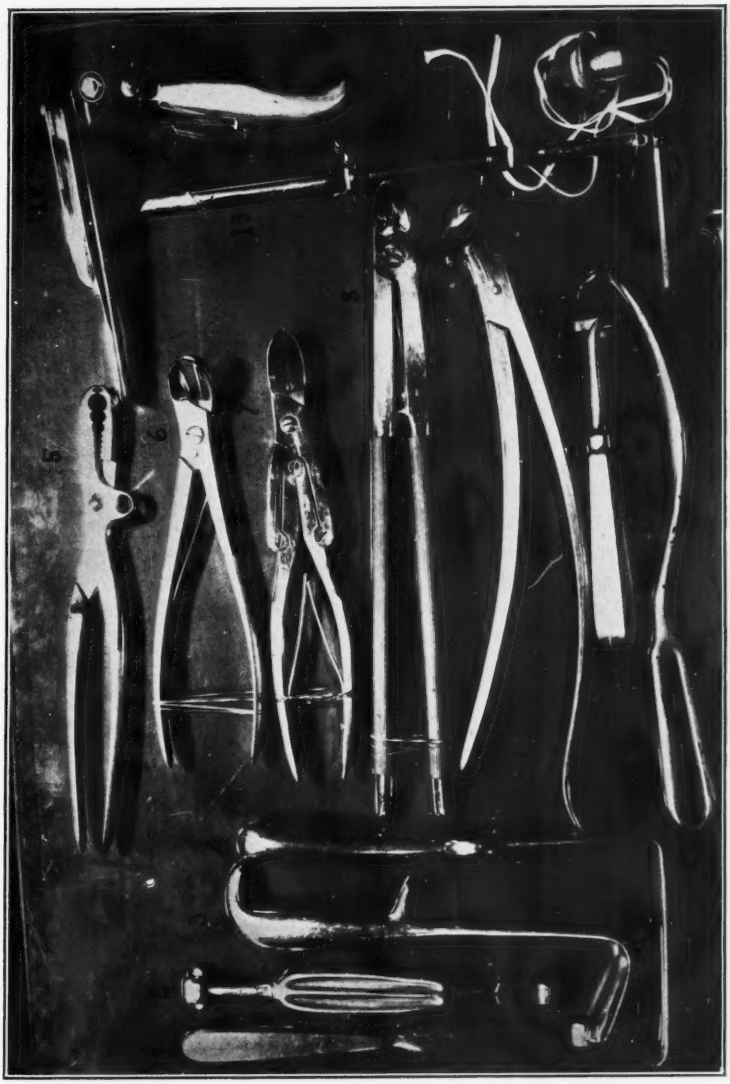


Fig. 5.—Instruments used by the writer:

1. Periosteum elevator, Maurer.
2. Periosteum elevator, Alexander.
3. Retractor, Matson.
4. Retractor, Doyen.
5. Bone clamp, Farabeuf.
6. Bone cutter with protected tip (right and left), Maurer.
7. Double action rib cutter.
8. Rib cutter of Bethune.
9. Costotome of Duval-Coryllos.
10. Costal periosteum elevator, Doyen.
11. Costal periosteum elevator, Maurer.
12. Laryngoscope.
13. Endotracheal catheter, Coryllos.
14. Mouth gag for same.

cases the whole operation was performed with the diathermic knife, with satisfactory results. This procedure has been abandoned, for it was found there was no significant change in the amount of bleeding with the use of the radio knife.

Preparation of the Operative Field. Benzin, ether and alcohol are successively used for cleansing the skin, which is then painted with two coats of alcoholic solution of picric acid. The operative area is surrounded with towels fixed to the skin with clamps, leaving uncovered only the necessary surface. The skin clamps are placed so as to indicate the three useful landmarks; that is, the line of the spinal processes and the beginning and the end of the incision.

Instruments. An effort was made to simplify the instrumentation. Besides the raspatoria of Hedblom and Alexander, I use the long handled periosteum elevator of Maurer, the periosteum elevators of Doyen and Duval, the costotome of Duval as modified by me, the rib cutter of Bethune, the Horsley's double action double curved bone cutting forceps and the bone clamp of Farabeuf. For retraction I use the retractors of Matson and a long narrow straight retractor (Doyen's vaginal retractor). No self-retaining retractor proved to be satisfactory. The curved cutters with protected points of Maurer are often very useful especially for section of the sternal cartilages of the first and second ribs (Fig. 5).

Incision. The incision begins at the level of the second spinal dorsal process at an equal distance from it and the spinal border of the scapula. It is not necessary to start higher or to section the fibers of the trapezius muscle above this level. The incision is then curved downward and forward and terminates in the posterior axillary line 3 cm. below the inferior angle of the scapula (Fig. 4).

The skin, subcutaneous tissue and muscles are sectioned in one stroke down to the ribs. The *Serratus posticus superior* is divided at the same time.

Hemostasis. All through the operation pads soaked in hot (110° F.) saline solution are used for packing and controlling oozing. After the incision is made, the wound is packed and the bleeders are rapidly clamped. Eight to twelve clamps are sufficient to insure temporary hemostasis which is made permanent by thermocoagulation only at the end of the operation.

Retraction of the Scapula. The connective tissue interposed between the serratus and the chest wall is rapidly disposed of, partly by sharp and mostly by blunt dissection and the scapula is hinged around its axillary border. This movement is checked by the insertions of the digits of the serratus to the first three ribs. I do not think it necessary to cut them, as Alexander[1] advises because this causes bleeding and opens the axillary space. They can easily be shoved off their costal insertions with a sponge (Fig. 6). This "unlocks" the scapula

which can be hinged away from the chest wall, giving an excellent exposure of the first, second, third and fourth intercostal space.

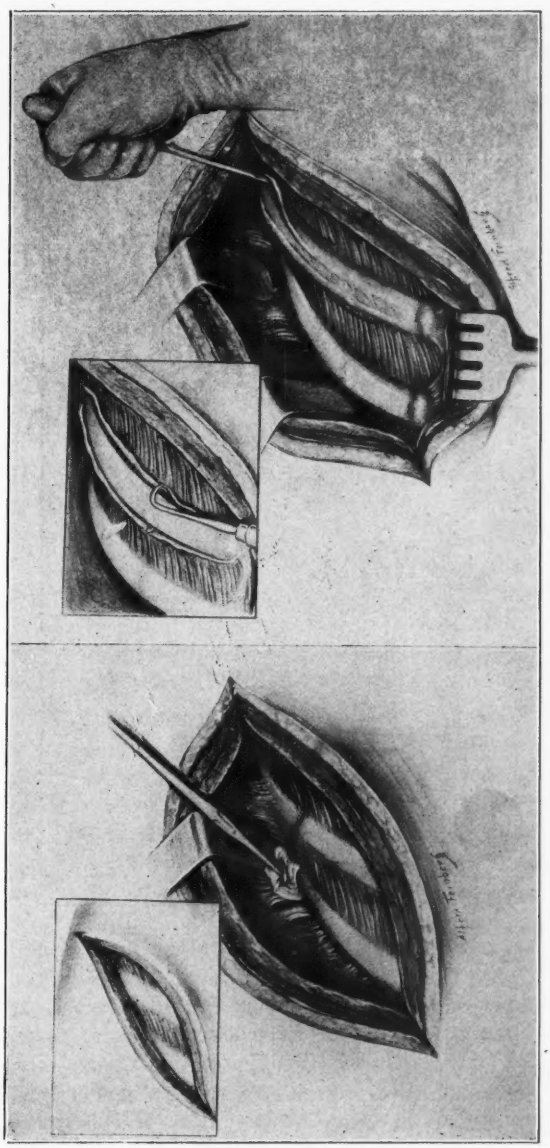


Fig. 6.

Fig. 7.

Fig. 6.—Scapula is retracted. Digitations of serratus muscle are detached from their costal insertions by blunt dissection by means of a sponge held in a sponge clamp.

Inclusion: Incision of soft tissues to the costointercostal layer.

Fig. 7.—Periosteum is detached from the external surface of the third rib. Elevation of periosteum from the costal borders is easily performed in following the arrows: toward the sternum for the superior border, toward the spine for the inferior border.

Resection of Ribs. The three first ribs are resected subperiosteally beginning with the third. The periosteum is incised on the external sur-

face of the rib and a narrow portion of it is scratched off the external surface of the rib with the periosteum elevator. Care is taken to keep the periosteum elevators always sharp. A dull elevator slides and becomes a dangerous instrument because it is impossible to keep it in contact with the bone and direct it with precision. The elevation of the periosteum from the rib begins at its inferior border as near to the sternal end of the rib as possible and is carried out, in one stroke,

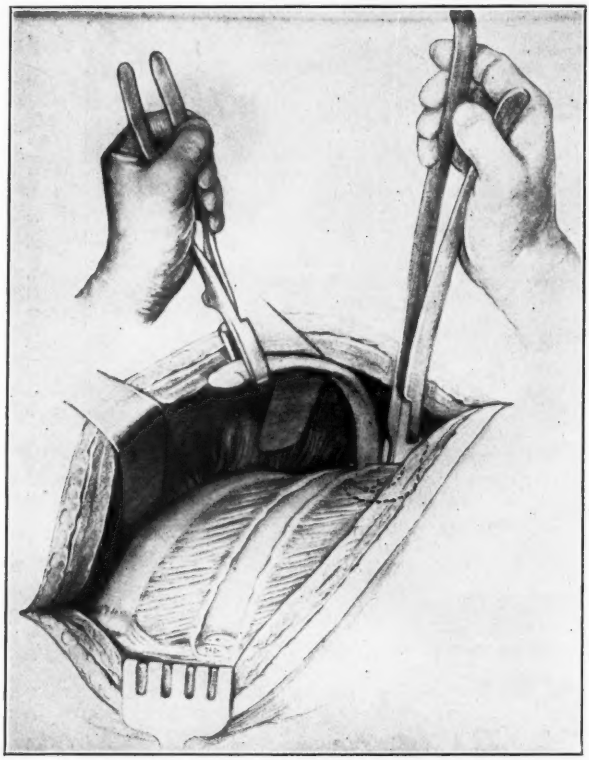


Fig. 8.—Third rib is sectioned posteriorly, seized with the bone clamp of Farabeuf and sectioned anteriorly with costotome of Duval. Notice the facility with which this costotome can be pushed toward the sternum.

from the costal toward the vertebral end of the rib. On the superior border, on the contrary, it starts as near to the vertebra as possible and is carried toward the sternum (Fig. 7, direction of arrows). This technic allows a rapid and safe elevation of the periosteum without danger of injury to the intercostal vessels. The periosteum is then elevated from the inferior surface in the posterior third of the rib, so that a tunnel is formed under the rib; the Doyen or Maurer periosteum elevator is introduced into this space, and the periosteum

on the inferior surface of the rib is stripped as far toward the sternum as possible; the same is repeated toward the vertebral end of the rib. The tip of the left index is then introduced through the intercostal space back of the neck of the rib, completing the elevation of the periosteum while the cutter of Bethune or Horsley sections the rib together with the tip of the corresponding transverse apophysis. The rib is then seized with the bone clamp of Farabeuf which gives an excellent hold on it and elevated so that its deep surface is exposed. The stripping of the periosteum of the sternal end of the rib is rapidly and safely performed by means of a sponge mounted on a long sponge clamp. (Fig. 9.) Thus any tearing of the pleura is avoided; a necessary caution for the success of this technic is the liberation of the inferior border of the rib from the intercostal muscles as far toward the sternum as possible. With this technic the rib can be resected in about one minute from the transverse apophysis to its sternal end without danger of injury to the pleura or to the intercostal vessels. For section of the anterior ends of the ribs I use the costotome of Duval modified by me for that purpose. The special curvature of the handle of this instrument and the small height of its cutting end make it possible to push it far down toward the sternum without any danger (Fig. 8).

Hemostasis is assured by the application of hot wet pads; with correct technic there are no bleeding vessels of any importance. The resection of the second rib is carried out in the same way; care is taken that anteriorly the sections are made at the junction of the rib with its cartilage. Exposure of this cartilage is easily accomplished by means of the sponge technic described above.

The resection of the first rib is carried out with the same ease, speed and safety as of the second and third, provided that a few details of technic are followed. The wide exposure due to the complete retraction of the scapula renders manipulation easy, although often we have to work at a great depth and in a rather narrow space; these difficulties are more marked on the right side. The periosteum should be incised directly on the posterior border of the rib, above and outside of the muscles of the first intercostal space in order to avoid injury of the intercostal vessels. For that purpose I seize, with the tips of the fingers of the left hand, the muscles of the first space and retract forcibly downward (enclosure of Fig. 9) so that the periosteum is elevated from the border by the same technic, using a particularly well-sharpened long handled Maurer's periosteum elevator. The inferior surface of the rib is easily separated from the periosteum with the sponge. The stripping of the superior surface is more difficult. However, by proceeding systematically from the posterior toward the anterior end of the rib with a sharp elevator which is not allowed to

lose contact with the bone and by constantly placing the tip of the left index finger in front of the advancing elevator we eliminate the danger of injuring the subclavian vessels. The only real obstacle to the complete stripping of this surface is the strong insertion of the *Scalenus anticus* on the tubercle of Lisfranc, at the anterior border of the rib. This phase of the operation is certainly facilitated by preliminary scalenotomy as has been done on 28 cases of my series. It is not necessary, however, to submit the patient to another operation for this purpose unless a phrenicectomy is contemplated. The severance of the insertion of the *Scalenus anticus* is completed with greater safety after section of the posterior end of the rib. The elevation of the periosteum from the anterior border offers no great difficulties because at this stage the stripped pleura tends to retract from the ribs with the collapsing apex. Caution must be taken at the posterior end of the rib to avoid any injury to the brachial plexus and to the first intercostal artery and vein which are often quite large. Hemostasis of these vessels has often proved laborious.

The section of the vertebral end of the first rib is done with Horsley's, Bethune or Maurer cutters; the left index finger of the operator protects the brachial plexus, while the assistant seizes the rib firmly with the clamp of Farabeuf. For additional safety a sponge is placed between the cut end of the rib and the brachial plexus. I twice saw and once myself had the disagreeable experience of injuring the plexus with the sectioned end of the rib which escaped from the bone clamp; the first rib is like a spring bent on its borders and firmly fixed at one of its ends; its elastic recoil is very great and therefore it is liable to produce considerable damage to the plexus. The rib is seized at its cut end is then turned around on its long axis, so that its superior surface (the patient considered in the erect position) can be turned out and downward. With the aid of the mounted sponge the stripping of the periosteum of the inferior surface is completed down to the costal cartilage (Fig. 9) which should be made clearly visible. The same procedure is repeated on the superior surface so that the cartilage can now be safely sectioned with the Maurer cutter. Often a simple nicking of the cartilage at its costal junction allows the disjunction of the rib from the cartilage. The strong costoclavicular ligament does not interfere with the resection of the first rib, at least not to the same degree as during the resection of this rib by an anterior skin incision as in the procedures of Iacobovici, Coffey, and Lawers.

The operation is now practically terminated. A hot pack is placed into the operative cavity, and hemostasis of the vessels which were clamped at the beginning of the operation is assured by thermocoagulation. There is no bleeding whatever deep in the wound, when no faults of technic have been committed. In the bottom of the wound the plexus and the subclavian vessels are clearly visible. This large re-

section of the three ribs causes complete collapse of the apex; one has the impression that the apex had been amputated with a cutting instrument at the level of the upper border of the fourth rib (Fig. 10).

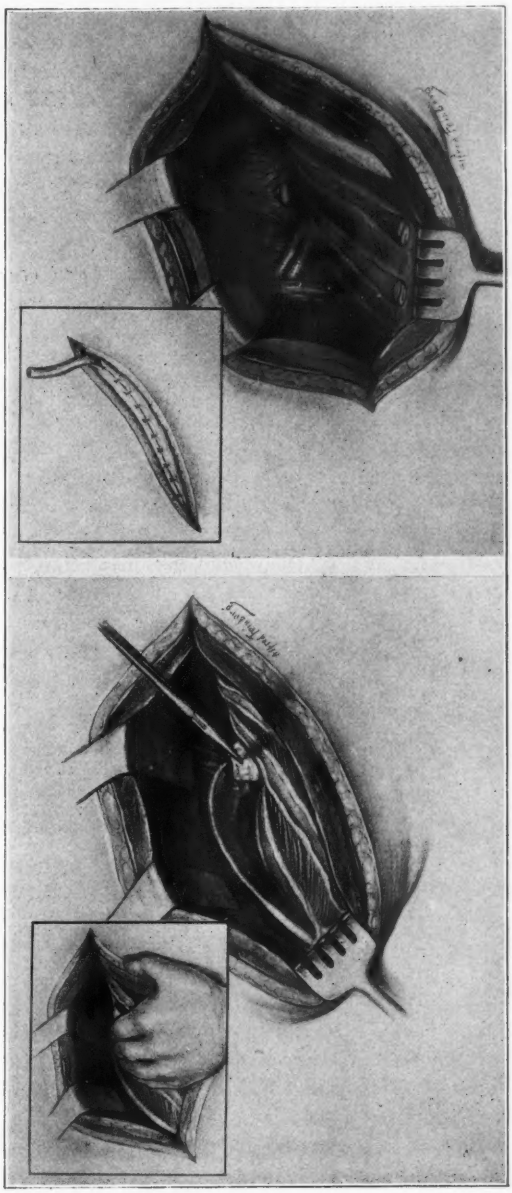


Fig. 9.

Fig. 10.

Fig. 9.—Preparation of the first rib. A sponge on a clamp liberates the lower surface. The costosternal cartilage is visible. Inclusion: Technic for the incision of the periosteum on the posterior border of the first rib.

Fig. 10.—Aspect of the collapsed apex after complete resection of the first three ribs. Posteriorly are shown the sections of the second and third ribs and of the tips of the transverse apophyses. The resected cartilage of the first rib is visible anteriorly. Inclusion: Suture of muscle and Penrose tube.

In cases in which the lower limit of the tuberculous cavity was visible in the x-ray films below the lower border of the third rib, I had increased the extent of the collapse by stripping the pleura from the endothoracic fascia to the height of the upper border of the fourth rib (8 cases). I do not feel, however, that I have obtained any great help from this procedure.

The posterior stumps of the ribs are now cut off with the rongeur of Sauerbruch. The cartilages of the first and second ribs and if necessary the anterior stump of the third rib are also cut. I perfectly agree with O'Brien that it is a sound measure to resect all the segments of ribs which in the x-ray picture are superimposed upon the cavity.

Ether is poured into the wound, unless the pleura has been accidentally opened, and a hot pad is placed in the wound, causing the rapid evaporation of the ether. Clots or tissue fragments are carefully removed. A Penrose tube is placed into the wound, its extremity protruding through the lower end of the incision (enclosure in Fig. 10).

The arm is then pushed backward so that the edges of the wound are approximated. A double chromic catgut No. 2 locked suture is placed through the muscles. A single running unlocked chromic catgut No. 1 suture is placed through the skin, loosely approximating its edges. Two or three dermal gut tension sutures are added. The duration of the operation varies between nineteen and thirty minutes, the average being twenty-two minutes.

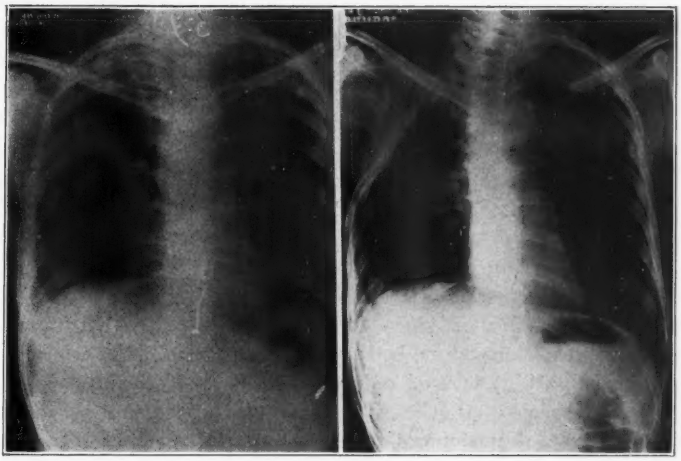
An alcohol soaked gauze sponge is placed on the incision and the wound dressed with dry gauze. The dressing is maintained with 2 inch adhesive bands, disposed like a fan from the shoulders to the back and the axillary surface of the operated side of the chest. No circular bands are used in order to avoid compression of the chest and interference with free respiratory movements of the healthy chest.

A thorough suction of the bronchi through the endotracheal tube is then made and the endotracheal tube removed.

An x-ray picture is taken routinely immediately after the operation; it serves as control for the subsequent films as it shows the condition of the lungs immediately following the operation. In cases of pulmonary complications this control film is particularly useful. At Seaview Hospital x-ray pictures are taken daily for the first eight days after operation.

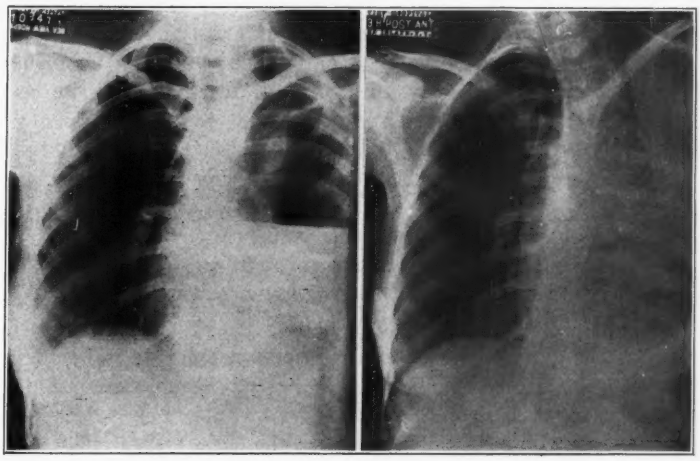
Subsequent Stages. The same technic is followed for the subsequent stages. No more than three, exceptionally four, ribs are resected in each of them. For the second stage I use the incision of the first stage, the scar of which is excised. For the third stage a new incision is made running parallel to the seventh space. When large segments of the sixth and seventh ribs are resected, a third stage is usually unnecessary.

Anesthesia is carried out for the subsequent stages in the same way as for the first stage; whether or not the endotracheal catheter is used depends exclusively upon the amount of sputum expectorated in twenty-four hours, as explained above.



A. *B.*

Fig. 11.—Case M. S. Apical thoracoplasty. *A*, Cavity in the right apex. Productive changes in the left apex. *B*, Resection of 5 upper ribs. Clinical cure. Sputum negative for tuberculosis.



A. *B.*

Fig. 12.—Five rib thoracoplasty. Case E. Ch. Cavities in left lung. Incomplete collapse with pneumothorax. (*A*) Resection of five ribs. (*B*) Clinical cure. Sputum negative for tuberculosis.

The results of an apical and a total thoracoplasty are shown in Figs. 11 and 12.

4. Postoperative Management.—The patient is placed on the operated side for from one to three hours; the foot of the bed is elevated. Oxygen and CO_2, 10 per cent, is administered through a double nasal catheter. The blood pressure is taken every half hour. The patient is encouraged to cough and expectorate, the nurse supporting the operated side. After he is out of the anesthetic, he is turned alternately on the operated and the healthy side of the chest. Blood pressure, pulse rate and respiration should be carefully followed; they are our guides in the postoperative care. It must never be forgotten that acute anoxemia can occur at any time during the first postoperative hours and that it can cause rapid death of the patient, already handicapped by moderate but prolonged anoxemia. Therefore a very close supervision must be exercised over these patients, and they must never be left alone during the first twenty-four hours following operation. An intravenous injection of from 400 to 500 c.c. of hypertonic NaCl solution (5 per cent) is given slowly. Cardiotonics are used if necessary. Ephedrine, caffeine-sodium-benzoate and strychnine are preferred. Digitalis (digifolin) is used only if necessary. Systematic preoperative digitalization of the heart is not applied, since I am convinced[3] that the cause of postoperative cardiac troubles is not in the heart itself but in the deficiency of the respiratory function. Cardiac disturbances in these cases are secondary to anoxemia, and treatment must be directed against this cause. Repeatedly, the most careful examination of the heart before operation and after convalesence in cases in which it gave us a great deal of concern during the postoperative period has shown no pathologic condition whatsoever. Transfusions were used only twice in the 43 cases (68 operations) of the third group. When blood pressure was not restored in a satisfactory way after hypertonic sodium chloride injection, normal saline solution was given intravenously until this result was obtained. From 1,000 to 4,000 c.c. were given for this indication without untoward effect; only in cases with pronounced and persistent anoxemia do we give the patient blood transfusions. Vomiting and blocking of the kidneys have been eliminated since the systematic use of hypertonic sodium chloride solutions was adopted.

The use of hypertonic solutions of sodium chloride is based upon experimental and clinical data upon the relation of sodium chloride metabolism to water balance. I cannot enter into greater details upon this extremely important question; its biologic and clinical significance and its application in thoracoplasties are at present being investigated at Seaview Hospital. Thus far we have found that decrease in chlorides both in plasma and in the cells is the rule after thoracoplasty, whereas the fluid collected from the wound shows a marked increase in sodium chloride. Far more interesting for us was the relation between anoxemia and variation in chlorides; this is suggested by the simultane-

ous decrease of oxygen content of the arterial blood and chlorides of the blood and their parallel return to the normal as the condition of the patient improves. I am not prepared to draw any conclusions as yet from this investigation. Clinically, however, there is no doubt that with the use of chloride solutions shock phenomena disappear very rapidly, vomiting and abdominal distention do not occur and that the patient can drink considerable amounts of fluids and retain them. Furthermore, an abundant diuresis is observed so that there is a close balance between intake and output of fluids. I was interested to learn from Dr. J. Alexander that postoperative gastrointestinal disturbances were frequent in his patients as long as he used glucose solution exclusively postoperatively. Personally I do not use glucose as I have no great faith in its value in thoracic cases.

Gum acacia (50 c.c. Lilly's solution) in 500 c.c. of triple distilled water has been used on 23 patients with excellent results. Its use has been discontinued since we started the use of hypertonic salt solution.

A word should be added about transfusions. There is no doubt that transfusions in postoperative cases, given in time, are life-saving measures. The most imperative indication for transfusion is very marked shallow rapid breathing, cyanosis and drop in blood pressure. I believe that in these cases we are dealing with advanced anoxemias due to the inability of pulmonary ventilation to satisfy the metabolic needs of the organism. Unaerated channels, obstruction of large bronchi or drowned lung render this organ unable to assure the passage into the blood of a sufficient amount of oxygen. This starts a vicious circle; anoxemia of the respiratory center lowers the threshold of its excitability to CO_2 and causes rapid shallow breathing which leads to excessive washing out of CO_2 and to increase of anoxemia because of the Bohr effect; loss of muscular and vascular tonus, due to acapnia, is produced, leading to peripheral blood stasis, decrease of the bulk of the circulating blood, drop in the blood pressure, further increase of anoxemia and death with symptoms of cardiac failure. Transfusions of whole blood, by bringing directly into the circulating blood sufficient amounts of oxygen and CO_2 relieve this advanced anoxemia, reestablishes normal function of the respiratory center and thus breaks the vicious circle. A study of O_2 and CO_2 content of arterial and venous blood before and after transfusions made by Dr. Pelecovich at Metropolitan Hospital has corroborated this hypothesis. Besides the rapid improvement of respiration and blood pressure, too rapid to be explained by the mere increase in volume of the blood of the patient, another important phenomenon was noticed in several of our cases of the first and second groups in which 5 and 6 rib thoracoplasties were performed. Patients with severe postoperative shock with pulse not palpable, corneal reflexes gone,

lower jaw dropping, complete limpness, and respiratory movements so rapid and shallow that they could hardly be detected, were able to cough and expectorate during or immediately after transfusion. The following case will illustrate this point.

V. S., white female, aged twenty-four years, had an upper first stage thoracoplasty in which 5 ribs were resected. Anesthesia was given without intratracheal tube. Thirty minutes after operation she became cyanotic and dyspneic and within thirty minutes her condition became critical. A transfusion of 500 c.c. of whole blood was given. Before the end of the transfusion the general condition had markedly improved and a strong attack of coughing occurred, which brought up a piece of thick mucus which when placed in water proved to be a cast of a large bronchus. The recovery from apparent death to what could be considered as a fair condition came with dramatic swiftness and was maintained. We were dealing with acute anoxemia caused by obstruction of a large bronchus.

For these reasons we avoid the use of narcotics so far as possible. It is better after all to let the patient be uncomfortable for a few hours and keep the respiratory center responsive than to decrease the activity of this center by narcotics. Codeine or pantopon in small doses is all that we use during the first twenty-four hours after operation and only when we cannot avoid it.

5. Accidents and Complications.—During Operations. Tearing of the pleura during operation had been either of no importance or on the contrary, of extreme seriousness. Where the parietal pleura was adherent to the lung, the accident has been harmless. It is peculiar, however, how seldom the pleura is sufficiently adherent to the lung to prevent the formation of a localized or even of an extensive pneumothorax. In fact in all my cases a more or less extensive pneumothorax was produced, although repeated trials before operation were unsuccessful in inducing pneumothorax. A careful suturing of the tear had always been made, reenforced when necessary with a piece of intercostal muscle. It is a different matter when tearing of the parietal pleura occurs in patients with hydro- or pyopneumothorax. The thickened pleura in these cases may be so friable that suture may become impossible. I had such an experience in the following case:

G. R., white male, aged twenty-nine years. Large cavities in the upper and lower right lobes incompletely collapsed by pneumothorax of eleven months' duration. A large amount of purulent fluid was present, which was aspirated the day before operation.

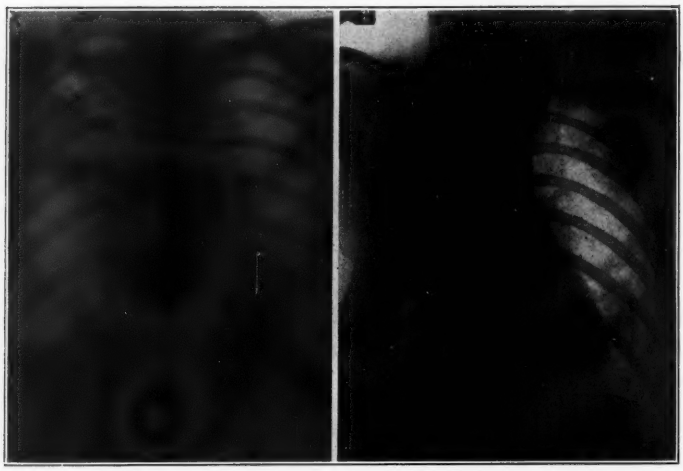
During the resection of the fourth rib a small tear of the pleura was produced, one inch in length. All efforts to suture it were in vain. Although a fine round needle was used and a piece of muscle was placed above the pleural opening, each suture cut the pleura and made the opening larger; after twenty minutes of futile efforts the wound was tightly packed. This patient developed a mediastinal flutter and died within thirty-six hours with signs of prolonged and severe anoxemia and cardiac failure which I was unable to control.

It is of interest to mention that infection may develop in an already present pneumothorax cavity following infection of the operative wound without tearing of the pleura; in one of my cases, and in two others I know of, a communication between the wound and the pleural cavity was established secondarily within a few days after operation, probably by ulceration and necrosis of the parietal pleura. This complication caused death in these three cases after prolonged suppuration. In my case, C. G., aged thirty-two years, white male, a 3 rib upper left thoracoplasty was performed for a large apical cavity. Pneumothorax had been carried on for eighteen months previous to the operation without collapsing the cavity. A moderate amount of fluid was present. The postoperative course was smooth for the first four days. On the fifth day patient had a marked chill and his temperature rose to 104°. Streptococcus was found in the sero-pus drained from the wound; all sutures were removed and the wound was dakinized. After an apparent improvement the temperature rose again. X-ray pictures showed a marked increase of the pleural fluid. Bacteriologic examination disclosed the presence of streptococci. Thoracotomy and drainage were performed, somewhat relieving the condition of the patient but septic temperature continued. All kinds of antiseptic solutions were used, including azochloramid which temporarily rendered the fluid aseptic. On the ninth postoperative day a communication developed between the pleura and the wound, which had not existed before. A second stage thoracoplasty was performed with the hope of collapsing the pleural cavity; the patient stood this operation better than I had expected and showed a marked improvement for the following three weeks. Unfortunately the condition of the patient became worse, and he died three months after operation with signs of amyloid nephrosis.

It is peculiar that the reverse, i.e., contamination of the operative wound from infected fluid, does not expose the patient to similar danger. In fact in thoracoplasties for closed tuberculous or for drained mixed infection empyema only exceptionally do we see infections of the operative wound; a plausible explanation of this fact is that in these cases either immunity has developed or the infecting organisms have lost their virulence, or both; on the contrary when wound infection secondarily contaminates a wide-open pleural space as in pneumothorax these two factors are not present.

Air Embolism. Does air embolism occur during thoracoplasty? I think we must admit the possibility of this complication although it is very exceptional. It happened twice in my experience. One occurred during thoracoplasty for bronchiectasis, the other during a second-stage thoracoplasty. Both patients were suddenly seized with convulsions, starting from the face in the first case, from the right arm in the second and rapidly becoming generalized. In both, attacks were repeated

several times on the operating table. Both died, twelve and eighteen hours respectively after operation. Unfortunately, an autopsy was not permitted in either case. It is not inconceivable that air could have been aspirated by a small vein present in a pleuropulmonary adhesion which may have communicated with the system of the pulmonary veins. Lilienthal believes that this may occur even in cases of old empyemas when air is introduced into them under high pressure. It is perhaps difficult to accept the mechanism described by this author, but it is even more difficult to overlook the above mentioned facts. Therefore it seems advisable in order to minimize danger to place the patient in a slight Trendelenburg's position during operation.



A. *B.*

Fig. 13.—Seven rib thoracoplasty. Case D. S. Multiple cavities in the upper right lung. (*A*) Resection of seven ribs. (*B*) Clinical cure. Sputum negative for tuberculosis.

6. Early Postoperative Complications.—Bronchial stasis and bronchial obstruction sometimes affecting larger bronchi but much oftener smaller-sized bronchi are the most frequent, the more dangerous and the least understood complications. Dr. Lloyd, at Seaview Hospital, has submitted to routine bronchoscopic examination 20 patients operated upon under ordinary mask anesthesia. In two of them he found complete obstruction of the lower lobe bronchus: one obstruction on the operated side and the other on the healthy side. Neither presented any clinical symptoms indicating this complication during the operation. This clearly shows that as a rule the origin of atelectasis is earlier than is generally believed. Another striking example is that of a young girl who suddenly died forty-eight hours after an extensive thoracoplasty performed under ordinary mask anesthesia;

death was attributed to "heart failure." Autopsy showed complete atelectasis of the contralateral lung. These facts again show the importance of bronchial obstruction and bronchial stasis in the postoperative course of these patients.

Aspiration Pneumonia and Bronchopneumonia. The so-called aspiration pneumonia falls in the same group with postoperative atelectasis. Birnbaum and I[4] have proved the etiologic, pathologic and pathogenic identity of these two complications and their relation to bronchial stasis. Routine laboratory examination for pneumococcus of the bronchial exudate removed through the endotracheal tube during operation, has shown that pneumococcus, generally group IV, was present in 72 per cent of 235 examinations and in 100 per cent when postoperative pulmonary complications occurred. This gives, I believe, a clear and definite explanation of the problem of aspiration pneumonia and indicates the usefulness of endotracheal anesthesia combined with removal by suction of the bronchial exudate.

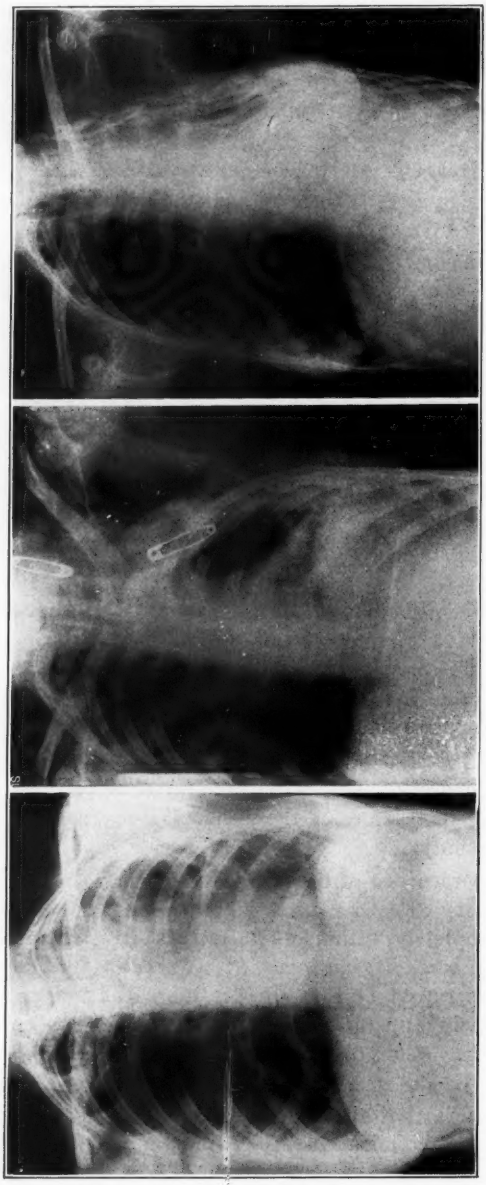
Infection of the Wound. I am not satisfied with the way my operative wounds have behaved. In the third group where I had the best results only 86 per cent had primary healing, of which 18 per cent had a slight superficial skin infection. In 8 per cent the infection extended under the muscles, and in 6 per cent it was necessary to reopen the whole wound. No death occurred from wound infection in this group, except in the case of the patient mentioned above who had a septic empyema in a pneumothorax cavity following infection of the wound with streptococcus. In my two previous groups, however, I had four deaths due to severe and prolonged wound infection and to amyloid nephrosis caused or increased by them.

Spread of the Disease. Autotuberculization. Extension of the disease early after operation is certainly connected, in part at least, with bronchial stasis. In these cases the mechanism seems to be the same as following hemoptysis.

In a certain percentage of cases, however, we deal with exudative spreads which may affect an extensive portion of a lobe and which may resolve completely within a relatively short time, from five to ten weeks. This complication occurred in three of my cases. In one of them the upper part of the opposite lung was infiltrated within four days following operation, showing a 3 cm. × 3 cm. annular shadow, and this lesion disappeared completely within six weeks (Fig. 14 *A, B, C*).

It seems possible that these "resolving exudates" are connected with the "autotuberculinization" following thoracoplasties, described by Thjotta (1922), Brunner (1924), and others more recently. One cannot, however, accept the mechanism proposed by these authors that tuberculinization is due to the "squeezing out of the collapsed

lung into the lymphatics and the circulation of tuberculin containing material," since it is known that in the collapsed lung both blood and



A. *B.* *C.*

Fig. 14.—Total thoracoplasty, 11 ribs—two stages. Case E. K. (*A*) Multiple cavitations of left lung. Productive and exudative lesions on the opposite lung, increased after first stage. (*B*) Annular shadow. (*C*) Clinical cure. Sputum negative for tuberculosis.

lymphatic circulation are slowed down or even suppressed. A more acceptable explanation, I believe, is that absorption of material con-

taining tuberculin takes place in the healthy lung following stasis of tuberculous bronchial exudate aspirated during operation or following the early postoperative period when expectoration is still absent. Absorption of tuberculin under these conditions may produce exudative reactions of a tuberculous nature around the existing lesions of the already sensitized pulmonary tissues. Another mechanism of extension of the disease into the healthy portions of the lung is by bronchogenic spreads; these may appear early after operation but more often constitute late complications which are generally related to incomplete collapse of the cavities of the diseased portion of the lung.

A word should be added here about "tuberculin shock" as a cause of rapid postoperative death. Gatto has shown that intravenous injection of tuberculin in tuberculous children causes a marked decrease of the globular resistance and produces hemolysis of red cells; bilirubin in considerable amount was found in the blood under these conditions. The same author reported that in these cases transfusion may aggravate hemolysis and cause rapid death.

In two of my cases I have noted unusual accidents which may be connected with tuberculin shock. A white man, aged thirty-two years, presented slight jaundice on the eighth postoperative day. A whole transfusion was given. At the end of the transfusion he had generalized convulsions and died ten hours later. "Tuberculin shock" seems to be a more rational hypothesis in that case than "toxic hemolytic icterus" which was diagnosed.

Hemotogenous spread occurred in only one case and was followed by death on the eighth postoperative day. Miliary tuberculosis was found at autopsy.

Hemoptysis. Hemoptysis occurring early after operation was seldom noticed in unilateral cases. On the contrary, in bilateral cases, when only one side was collapsed, it was of a rather frequent occurrence. In the case of a white woman, aged twenty years, with extensive cavitation in both apices, a first-stage (3 ribs) upper thoracoplasty was performed. The postoperative course was uneventful for the first four days. On the fifth day she had a severe hemoptysis in the morning which was repeated in the evening; the patient died with symptoms of drowned lung and acute anoxemia.

Spontaneous Pneumothorax. Exceptionally pneumothorax may develop on the operated side or even on the contralateral side, during the postoperative course, without any operative injury to the pleura. It appears in cases having pneumothorax before operation. This complication occurred three times in my series. In two death followed; one patient has recovered.

I deem it of interest to present briefly the history of one of these cases:

R. G., white male, aged twenty-one years.

Onset of disease August, 1931, with cough, expectoration and hemoptysis. Sputum was Gaffky 5 to 8.

Clinical and x-ray diagnosis: Caseous pneumonic tuberculosis with 2 large cavities in the upper left lobe and seeding to the lower lobe. Slight infiltration of the right lower lobe. Persistent temperature 100° to 102°. Bed rest did not improve this condition. Pneumothorax in November, 1932. Spontaneous pneumothorax occurred a few days later followed by development of fluid. After repeated deflations the bronchial fistula seemed to have temporarily closed. Examination of fluid was negative for tubercle bacilli and pyogenic organisms. Because of repeated attacks of spontaneous pneumothorax it was decided to collapse the left chest. Sputum 60 c.c. in twenty-four hours.

December 15, 1932, phrenicectomy and scalenotomy were performed. Postoperative course uneventful.

February 1, 1933. Upper stage thoracoplasty under regional anesthesia. Endotracheal catheter was used. The 5 upper ribs were resected. Postoperative course satisfactory until the eighth day when he again developed a spontaneous pneumothorax. Aspiration of 1,000 c.c. of air, repeated the next day, was followed by marked improvement. Wound healed during the third week.

March 5, 1933, second stage. Regional anesthesia. Endotracheal tube and suction. Five ribs resected.

The third postoperative day dyspnea and cyanosis developed. Blood pressure 110/84. Four hundred c.c. of fluid were aspirated from the pleural cavity; at the end intrapleural pressure was −10 −4. Two days later a new attack of dyspnea and cyanosis. Intrapleural pressure +14 +18. Fourteen hundred c.c. of air were aspirated with marked improvement. In the evening a similar attack occurred. A needle of large size was introduced into the pleural cavity, connected with a tube the end of which was under water. The patient was temporarily relieved; but he died with symptoms of anoxemia and cardiac decompensation twenty-four hours later. Autopsy was not obtained.

Kinking of Bronchus. In a man aged twenty-eight years death occurred with symptoms of acute anoxemia under conditions which suggested that death was due to mechanical obstruction of the bronchus of the healthy side.

C. C., male, aged twenty-eight years, white, had tuberculosis of the whole right lung with extensive fibrosis; very marked displacement of the heart, trachea and diaphragm toward the right side. Complete dextrocardia was present with marked vicarious emphysema on the left side.

Onset of tuberculosis July, 1923. Hospitalization in Bellevue Hospital and Raybrook Sanatorium. He returned to Bellevue in 1927. He again went to Raybrook in 1928. Pneumothorax produced only incomplete collapse and was abandoned. The x-ray findings were retraction of the right chest and thickened pleura. Two irregular areas of aeration in the middle and the basal portions of the lung, probably localized pneumothorax; the upper presents a fluid level. R. U. L. atelectatic. Productive changes in the root of the left lung. Marked displacement of the trachea, mediastinum and the heart to the right.

Thoracoplasty on May 21, 1932. Endotracheal anesthesia, ether gas oxygen. Five ribs resected (first to fifth respective lengths 10, 12, 16, 18 and 20 cm.). Fair recovery.

Second stage, June 18, 1933. Endotracheal anesthesia. Ether gas oxygen. Sixth, seventh, eighth and ninth ribs resected. Respective lengths 17, 18, 18.5 and 18.5 cm. Suddenly at the end of the operation the patient became cyanotic, and 12 c.c. of foamy foul smelling fluid were aspirated from the bronchi. O_2–CO_2 was administered through the endotracheal tube and produced marked improvement.

Postoperative: During the night of operation patient repeatedly expectorated sputum of offensive odor.

June 19, 1933, 5 A.M. attack of dyspnea and cyanosis. Patient was becoming asphyxiated. Emergency bronchoscopy was performed with the intention of aspirating pus probably blocking the left bronchus. This showed the right bronchus filled with thick foul sputum. The left bronchus was kinked so that its lumen was one-third normal. When the bronchoscope (7 mm. Jackson) was introduced into the left bronchus, respiration became easier and cyanosis decreased considerably. Dyspnea started again when the bronchoscope was removed. Patient's condition became worse. Bronchoscope was placed again and the patient transferred to the Drinker apparatus. Condition seemed improved but after two hours it declined again and the patient died at 1:30 P.M. Autopsy was not obtained.

It seems that in this case the cavity of the hydropneumothorax mentioned in the x-ray report was really an encapsulated pyopneumothorax which was evacuated during the second-stage operation into the right bronchus partially obstructing it; this explains the attack of cyanosis and its relief following aspiration of 12 c.c. of pus. The left common bronchus, forcibly pulled toward the right side of the chest before the operation, was kinked after the second stage, but it could still allow sufficient oxygenation. Following the additional collapse of the right lung after the second stage all the burden of respiration was thrown upon the left lung, already impaired by the kinking of its bronchus. The pus coming from the heretofore encapsulated pyopneumothorax increased the partial obstruction of the left bronchus and led to repeated attacks of acute anoxemia and death. This explanation was suggested by the bronchoscopic and clinical findings. I have not been able to find any similar case in the literature.

Compression of the Large Veins and of the Right Heart. This complication is not rare. It was apparent in one case in which a Bernou-Casper operation with packing was performed. Very rapid pulse followed by arrhythmia occurred shortly after operation, which was relieved with the removal of the packing. The cause of cardiorespiratory disturbances following extensive thoracoplasties, especially on the right side, is due, I believe, to the easier compression of the large veins and the right auricle. To this complication a number of authors have attributed their higher mortality in thoracoplasty upon the right chest. As will be shown in Table VIII such predominance was not found in my cases.

Late Complications. Complications due to thickened pleura and previous pneumothorax, hydro- or pyopneumothorax.

In a number of thoracoplasties performed upon patients with air and fluid still present in the chest, with no other organism present in

the fluid than tubercle bacilli, perfect collapse was obtained notwithstanding the presence of a thickened pleura, and the sputum became persistently negative.

In other cases, however, the pleura was so resistant that satisfactory collapse of the deribbed chest could not be obtained. It is an open question in my mind why in a number of cases with thickened pleura a good collapse was obtained and in others although the pleura was of about the same thickness no satisfactory collapse occurred. It is known that in a pleural cavity with rigid walls complete absorption of the air of the pneumothorax can occur. On the other hand, it is possible that exchange of gases and especially of oxygen through the chronically inflamed pleura and in the underlying atelectatic and sclerotic lung may be decreased to such an extent that the air of pneumothorax cannot be absorbed. In both cases a mechanical obstacle to the collapse of the chest wall is offered.

Incomplete collapse is not the only complication due to prolonged pneumothoraces especially when purulent exudate is present. In one patient with tuberculous pyopneumothorax well tolerated for over a year, bronchial fistula had developed followed by secondary infection of the fluid. Thoracotomy was performed, followed by thoracoplasty. In the meantime, however, the other lung was contaminated, probably by the pleural fluid which contained tubercle bacilli. This patient has now recovered from the empyema but is in the hospital because of the lesion in the other lung. I have had two similar cases.

Therefore it seems reasonable to admit as a principle that when pneumothorax is not able to produce an adequate collapse of the lung, it should be interrupted in time and replaced by thoracoplasty. For similar reasons I consider that oleothorax has done more harm than good, at least in my experience. In fact, in cases in which oleothorax is indicated, if a thoracoplasty is feasible, I do not hesitate to give all preferences to the second.

Bronchiestasis (Fig. 15). Marked bronchiectasis has been a rather rare complication in my cases. On the contrary, a moderate degree of bronchial dilation is frequent in tuberculosis and perhaps more so after thoracoplasties; it should always be suspected when the amount of sputum remains high or increases, although it remains constantly negative for tubercle bacilli. It is definitely diagnosed by bronchograms following lipiodol injections. In the great majority of cases it remains more or less latent. In one of my cases death occurred, one year after complete thoracoplasty with persistently negative sputum, from repeated and profuse hemoptyses which could not be checked. I have been so impressed by this case that in the future I shall not hesitate to perform a pneumonectomy for advanced and especially for bleeding bronchiectasis.

Deformities. Scoliosis is the most frequent deformity following complete thoracoplasty. It occurred more frequently in young patients, especially under fifteen years of age. The prolonged use of orthopedic braces following operation in young patients was found useful in preventing this complication. However, the most marked scoliosis in my cases was produced in a female, aged twenty-eight years, whereas in a young girl aged fourteen years no noticeable deformity developed after a complete thoracoplasty. Usually, even in total thoracoplasties there was neither deformity nor impairment of function (Fig. 18*C*, *D*, *E*).

No impairment of function of the upper extremities was observed in my cases. In two cases, however, in which 4 ribs were resected, the scapula was "locked" because of adhesions connected with the fifth and sixth ribs. One had the impression that the lower angle

A. *B.*

Fig. 15.—Saccular bronchiectasis in tuberculosis. Case C. B. *A*, Chronic caseous pneumonic tuberculosis of left lung. *B*, Lipiodol injection.

was beneath these ribs. Resection of the fifth and sixth ribs and liberation of the scapula relieved this condition.

Injury to the Brachial Plexus. This is a more serious complication. It occurred in one of my cases, with motor impairment of radicular distribution, limited to the territory of the lower stem. There was restoration of movement seven months after operation, and muscular atrophy gradually disappeared.

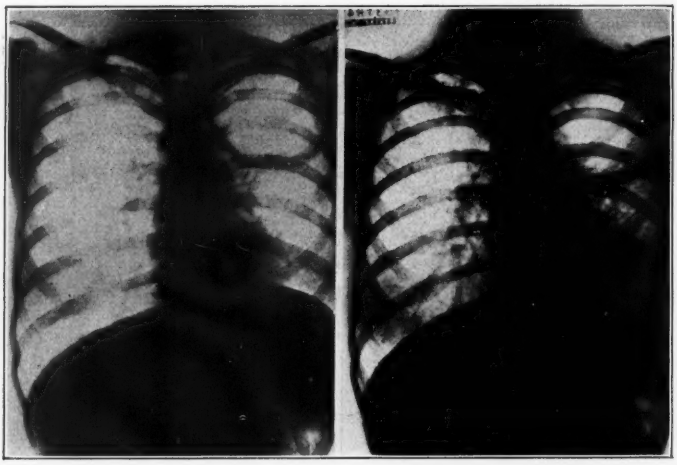
Failure of Thoracoplasty to Collapse Cavities. Thoracoplasty does not always succeed in collapsing cavities. To some extent it can be predicted whether a given cavity will close or not following thoracoplasty. Peripheral and external cavities of moderate size situated away from the mediastinum and small multiple cavities collapse in

75 per cent to 85 per cent of cases. On the contrary, cavities situated near the mediastinum are more difficult to close.

Very large apical cavities with the apex almost completely shelled out often present great difficulties and necessitate repeated operations. A typical case is the following: (Fig. 16.)

C. J., white female, aged sixteen years, admitted to Seaview Hospital September 17, 1926. Onset of disease October, 1925. Diagnosis: Caseous pneumonic tuberculosis of right lung, with large cavities 6 cm. × 6 cm. in right apex. Bed rest, pneumothorax (1929) and phrenicectomy (1930) were unsuccessful. Persistently positive sputum (Gaffky 6-10). Thoracoplasty. Because of very profuse expectoration and marked dyspnea thoracoplasty was begun with the lower ribs. (This is the only case in the series where this technic was used.)

First stage (Sept. 4, 1931) seventh, eighth, ninth, tenth and eleventh ribs resected.



A. *B.*

Fig. 16.—Case J. C. Repeated operations were necessary to close a huge left apical cavity (*A*), (June 7, 1929) which had further increased notwithstanding phrenicectomy (*B*); two stages total thoracoplasty did not close the cavity (Jan. 9, 1932).

Second stage (Sept. 29, 1931) fifth, fourth, third, second and first ribs. Apical cavity was only partially collapsed, and sputum remained positive.

Third stage, anterolateral thoracoplasty (May, 1932). Complete resection of anterior and posterior segments of first, second, third and fourth ribs by an axillary approach. Condition was improved but sputum still 1 to 3 ounces in twenty-four hours and positive (Gaffky 3-8).

Fourth stage, posterior pneumolysis after resection of regenerated bone of second, third, fourth and fifth ribs and packing with gauze. Within three weeks sputum was negative, cough and expectoration ceased and the patient became an ambulatory case. A draining sinus with a bronchial fistula remained after pneumolysis, which warranted further surgical treatment.

Fifth stage (Oct. 7, 1933), dissection of sinus and application upon bronchial fistula of a pedunculated muscular flap. Closure of bronchial fistula and of sinus

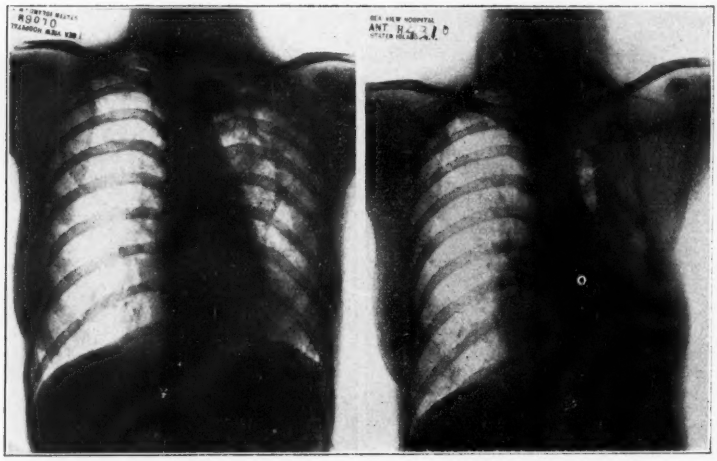
were successful. Patient remained bacilli free, increased considerably in weight; cough and expectoration disappeared, and she has been on full activity since then.

C. *D.* *E.*

Fig. 16.—Same case as shown in Fig. 16, *A* and *B*. (*C*) Anterolatral thoracoplasty and later pneumolysis with packing (Feb. 9, 1933) were successful in closing the cavity and insuring permanently negative sputum (*E*).

Another factor which may oppose the closure of cavities is the conformation of the chest. The so-called pancake chests, broad in the frontal plane and shallow in their anteroposterior diameter, often

present incomplete collapse notwithstanding the considerable length of the resected costal segments. These chests are more frequent among colored patients. In such cases special attention was given to resect almost the total length of ribs in order to avoid supplementary anterolateral thoracoplasties. The latter, in my experience, seldom were successful because regeneration of the posterior segments generally prevented good collapse. Unless we again resect these segments the anterolateral thoracoplasty has little chance of collapsing the cavity. In these cases extreme resection of the ribs and a pneumolysis with prolonged compression with gauze gave a more satisfactory result. The case mentioned above (C. J.) is a good example of the efficiency of this procedure.

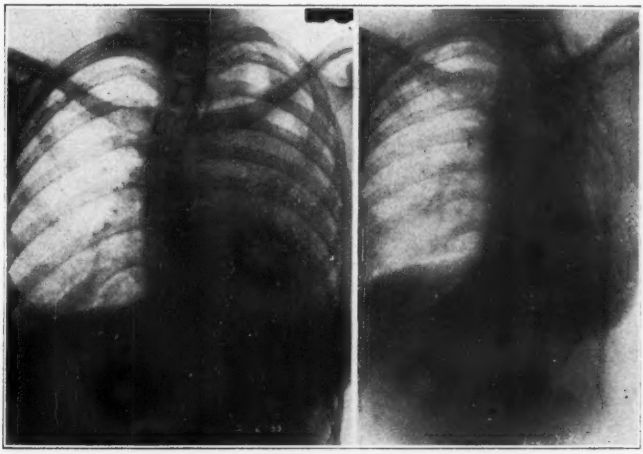


A. *B.*

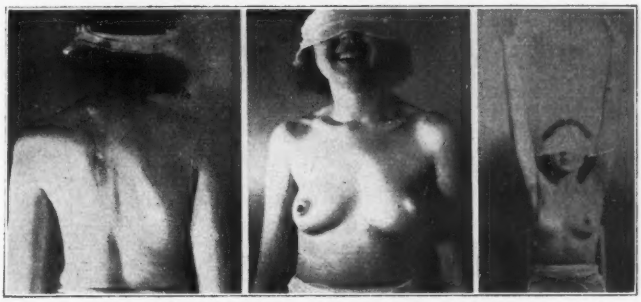
Fig. 17.—Case F. R. Large cavity upper left lobe (*A*). First rib not resected. Anatomically unsuccesful collapse (*B*). Clinical results perfect. Sputum negative for tuberculosis.

Persistence of Positive Sputum. In a limited number of cases notwithstanding an anatomically satisfactory thoracoplasty and a marked improvement of the patient the sputum remained positive three and four months after operation. In the case of a colored man with pancake chest, the sputum became negative only after five months following operation and it has remained so since. In another, a white man twenty-five years of age, the sputum became negative only after eleven months following operation. In my experience we should not rush to perform more surgery upon these cases if cavities are not seen with absolute certainty in the radiograms. I say "with absolute certainty" because it is very difficult to say whether a cavity is still present or not on the operated side where a bony lace

formed by the regenerated bone is generally present. On the other hand, it should not be forgotten that following a correct thoracoplasty there is progressive development of fibrous tissue in the collapsed lung so that shrinkage of the parenchyma, closure of the small bronchi and atelectasis gradually and steadily progress, leading to the cure of the disease.



A. B.



C. D. E.

Fig. 18.—Case J. V. Caseous pneumonic tuberculosis of left lung. Pleura thickened and very resistant to collapse (*A*). Although total thoracoplasty had produced anatomically unsatisfactory collapse (*B*), the clinical result has been perfect. Persistently negative sputum. Notwithstanding extensive thoracoplasty (11 ribs) there is neither deformity (*C, D*) nor impairment of movements (*E*).

In a general way we can say that when the number of bacilli in the sputum has markedly decreased after thoracoplasty we should wait before deciding on a supplementary operation. On the contrary when the Gaffky remains unchanged, and there is no lesion in the contralateral lung accounting for a high Gaffky, the collapse of the

diseased chest should be completed. In a colored woman, thirty-six years of age, sputum remained positive (Gaffky 4 to 8) after a three-stage thoracoplasty. It was impossible to say with certainty whether the cavities were closed or not. Seven months after the last stage the regenerated third, fourth, fifth and sixth ribs were resected extensively. The sputum became negative after eight days following operation and remained so since.

Nonremoval of the First Rib. In one of my cases the first rib was overlooked during the first operation. In another it could not be taken

Fig. 19.—Case B. D., 3 ribs resected in apical thoracoplasty. Total resection from transverse apophysis, inclusively, to costal cartilage. A cervical rib was present in this case which was also resected.

out because the patient had a marked degree of shock during the operation.

In the first case (Fig. 17) the removal of this rib at a later stage was decided upon. The operation was postponed temporarily because the sputum became negative after the operation. The rib has never been removed because at present, two years after operation, the patient is still in perfect condition; the sputum has remained negative, and she is gainfully employed.

I know of two other similar cases. They show that even a moderate degree of collapse may produce closure of a cavity; they further

support the opinion that collapse of cavities is not caused by compression (intrapleural pressures are never positive in thoracoplasties) but by closure of the bronchial outlets of the cavity. A moderate pneumothorax may act in the same way, and certainly only this mechanism can explain spontaneous closure of cavities. This point gives the explanation of the puzzling cures with thoracoplasties anatomically unsatisfactory (Fig. 18) while, in other cases, perfect thoracoplasties fail to close cavities. These cases cannot be understood if we consider that collapse of the cavities is produced by "compression."

I do not think, however, that we should conclude from these rare cases that we can afford to leave the first rib intact or to resect only a small segment of it. The only lesson to be drawn from these three cases is that we cannot consider that failure to resect the first rib necessarily means unsuccessful operation. It is good to have this point in mind in case of shock during the operation.

Cervical Rib. In one case a 3 cm. cervical rib was present, the technic was carried out as described above. The liberation of the first rib was somewhat more laborious than usual because the tip of the cervical rib was firmly attached to the first rib. Fig. 19 shows the segments of the three ribs and the cervical rib resected in this case.

INDICATIONS FOR THORACOPLASTY

In the routine work of our medicosurgical conferences, our group has endeavored to answer the following questions: (1) What are the cases which should be operated upon? (2) When should they be operated? (3) How should they be operated upon?

These questions are far from being always easily answered. We have arrived, however, at a number of conclusions upon which our present conceptions of operative indications are based.

1. What are the cases which should be operated upon? (Choice of cases.) We do not base the answer to this question upon the duration of the disease, its location, extension or upon the general condition of the patient. It is principally, and I could say exclusively, based upon the "nature" of the disease. In the choice of patients we have been greatly helped by the classification of Ornstein, Ulmar and Dittler. The distinction of the acute from the chronic forms of pulmonary tuberculosis and the separation of the latter into resolving forms which can be considered as benign and into caseous pneumonic or ulcerating forms which should be considered as the malignant forms of the disease, have thrown, I believe, a new light on the question of operative indications. We have come to consider the chronic proliferative or productive forms as nonsurgical, provided that no cavities are present. Sputum in these cases is negative or occasionally positive and not higher than Gaffky 1 or 2. Surgical as well as medical treatment has

very little if any influence upon these slowly progressive, often ignored and as a rule perfectly well-tolerated lesions. This fact is of importance because a number of the so-called "good risks" for thoracoplasty belong to this class; it is questionable whether their "cure" by surgical procedures can be attributed to the operation. This is shown by the fact that a great number of my cases with caseous pneumonic tuberculosis on one side and chronic productive on the other, although operated on only on the side of the caseous pneumonic lesion, were cured and behaved as unilateral cases (see Tables III and IV).

The acute exudative resolving forms do not require surgical treatment any more than do the productive forms. As a rule they recover spontaneously under simple bed rest within a few weeks to a few months. The whole question of operative indications thus evolves around the accurate diagnosis of the form of tuberculosis with which we are dealing. This diagnosis is difficult if not impossible at the acute phase of the disease. A benign exudative form can be suspected, however, by its lesser toxicity, better general condition of the patient, smaller numbers of bacilli in the sputum and the fewer stethoscopic signs considering the radiographic extent of the disease; it is the opposite in the caseous ulcerative forms. Within five to fifteen weeks the diagnosis becomes easy, since at this time the benign forms show a more or less advanced resolution whereas in the caseous pneumonic forms cavities appear following the elimination of the sloughed-out pulmonary tissue.

It has often been said that this classification is not reliable because there is no such thing as an exclusively resolving form or an exclusively ulcerating form of tuberculosis. Pathologically this is true, and Tendeloo has long ago shown it. Clinically, however, predominance of one of these two forms is usually so marked that we can consider them for surgical purposes as pure forms, with the restriction that whenever even a small cavity is present the exudative element should be disregarded and the case should be diagnosed as caseous pneumonic and ulcerative form.

These considerations show the advantages of the "qualitative" classification over the simply "quantitative" of the National Tuberculosis Association. As with tumors it is not the size of the lesion but its nature which is the important element in the prognosis and the choice of treatment.

It is thus evident that before any surgical treatment is decided upon, time should be allowed for an accurate diagnosis of the form of tuberculosis of the individual case with which we are dealing. Hasty application of pneumothorax or phrenicectomy leads to erroneous estimations of the curative values of these methods and explains the

unwarranted enthusiasm of a number of authors who have overlooked the fact that all benign exudative cases were cured not because of but in spite of the treatment. I cannot subscribe to such opinions as that pneumothorax induced at the acute period prevents the disease from becoming chronic; nor do I believe that it is a trifling matter to give pneumothorax, which, once begun, should be continued for several years or to perform routinely phrenicectomies in the acute stages.

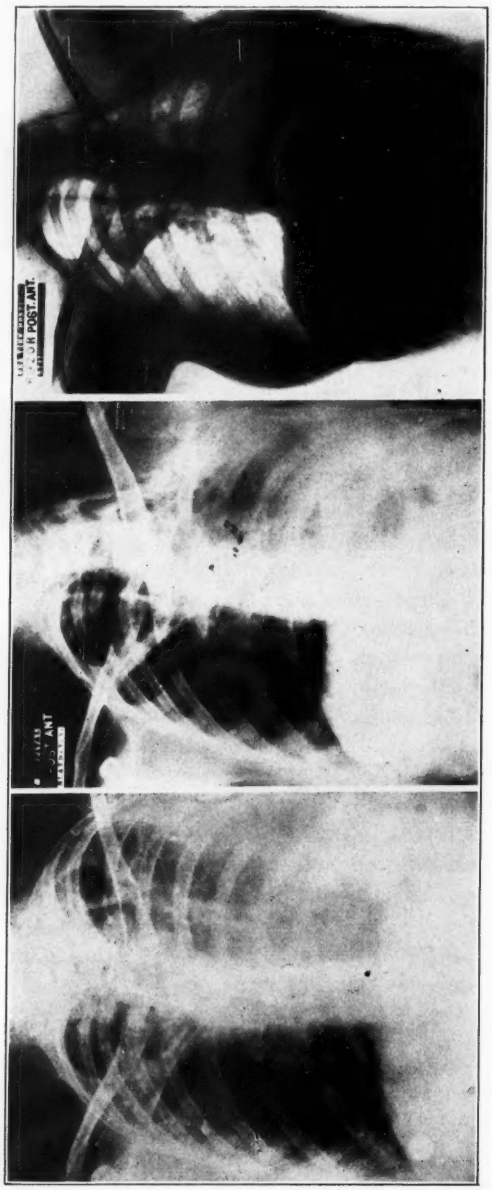
On the contrary, when the presence of a real cavity has been ascertained, I believe that no time should be wasted with the optimistic view of a spontaneous closure or with trials of phrenicetomy which offer no greater percentage of cures than spontaneous closure. I do not mean that phrenicectomy has never cured a cavity. Partial collapse of the lung due to paralysis of the diaphragm can, like a pneumothorax of 250 to 350 c.c. of air, occasionally bring about collapse of the draining bronchi of the cavity and its subsequent closure. But this is so uncertain that I do not believe that we have the right to lose precious time with trials of uncertain procedures and expose the patient to an extension of the disease which can occur at any time.

I wish to make clear the points I have already referred to at the beginning of this paper. I consider that a patient who has a tuberculous cavity and highly positive sputum must have the lung collapsed without delay unless there are definite and imperative contraindications. I place such a patient in the same category with patients who have an acute appendix or, better, a tuberculous kidney. As in the latter we should act before the disease has become unmanageable. I do not believe that hemoptysis, tuberculous laryngitis or even a moderately advanced tuberculous enteritis constitute contraindications. The only way to cure these complications is to collapse the diseased lung and eliminate the source of tubercle bacilli.

With lesions limited to one lung, even extensive, collapse treatment is definitely indicated. There are no differences of opinion on this point.

The question becomes more difficult when we consider bilateral lesions. Our group of workers has arrived at the following conclusions on this question. With cavities in one lung and lesions in the other lung of the chronic productive variety, unless the latter are so extensive as to very markedly decrease the respiratory field, there is no contraindication to thoracoplastic collapse of the caseous pneumonic side. When cavities are present in both lungs, the operability of the patient depends upon their extension and chiefly upon their location. In bilateral apical lesions we should collapse both apices. When apical lesions are present in one lung and extended lesions in the other and the condition of the patient is not too desperate, we

collapse the apex which shows the more advanced lesions, leaving to a later date the procedure to be applied upon the other lung, pneumo-



A. *B.* *C.*

Fig. 20.—Case E. F. *A*, Bilateral apical cavities (June 4, 1932). *B*, Left (May 18, 1932) apical thoracoplasty succeeded in closing left cavities. *C*, Selective pneumothorax on right apex brought about temporary closure of right cavities. Sputum occasionally positive for tuberculosis.

thorax, apicolysis or thoracoplasty (Fig. 20). There can be no fixed rules for all cases and especially the ones at the borderline of oper-

ability. Pulmonary tuberculosis is such a protean disease, and we know so little as yet about the factors which determine its evolution that we must not shrink, within reasonable limits, from even apparently desperate efforts. These are precisely the cases upon which skillful combination of operative procedures, pneumothorax, thoracoplasty, apicolysis, etc., can give unexpected results; and it is toward this direction that our efforts should be directed. Of the cases presented here 65 per cent had bilateral lesions. It is to be hoped that by using efficient methods and using them in time we shall be able gradually to prevent a great number of cases from becoming far advanced.

2. When should we operate? (Choice of time of operation.) I believe that we have not as yet sufficiently recognized the paramount importance of the factor "time" in the management of pulmonary tuberculosis. Unwarranted procrastination, prolongation of "bed rest" and delays of a "few months" at a time have been used without real discrimination. I cannot understand the reasoning that because 10 to 20 per cent of cavities may cure spontaneously we are permitted to expose the remaining 80 per cent to what we know to be certain death. It seems to me far more rational to reason the other way around. Since we know that cavities even small in size if left uncollapsed constitute a death sentence in 80 per cent of patients, that thick-walled large cavities develop from the small cavities, that small cavities are easy to collapse, that no harm can be caused by a timely collapse even to the fortunate 10 to 20 per cent who may cure spontaneously and that there are as yet no means by which we can foretell whether a given cavity is going to cure spontaneously or not, for all these reasons we are not justified in delaying collapse treatment. Nothing is more dangerous for the patient than that type of procrastination so often confused with conservatism. It is more conservative, I believe, to save the life of a patient by active and even radical measures than to jeopardize it by injudicious inactivity. I believe that until some medical and more efficient treatment than surgery is found for pulmonary tuberculosis we must follow the same lines of reasoning which we know to be correct in other diseases, such as in the cases of appendicitis or tuberculous kidney.

3. How shall we operate? (Choice of procedure.) I have already given my ideas upon the comparative values of pneumothorax and thoracoplasty as compared to apicolysis, phrenicectomy, etc. I shall briefly state here the lessons taught by my experience with the cases reported here.

When the cavities are exclusively located in the apex of one lung, the method of choice is apical thoracoplasty. It does not matter what the size, character of the walls or number of the cavities may be, provided that we are certain that true cavities are present.

In bilateral but exclusively apical lesions the method of choice is bilateral apical thoracoplasty if the condition of the patient is fair and if he does not have frequent hemoptysis. In the latter cases it is preferable to first perform a temporary apicolysis with plombe upon the more advanced side and from one to three weeks later proceed with an apical thoracoplasty on the other side; in this way we may avoid the danger of a hemoptysis from the contralateral and as yet uncollapsed side, following apical thoracoplasty. Apicolysis, although less effective than thoracoplasty, is a much more benign operation and permits the performance of a thoracoplasty on the other side with less danger of a fatal hemoptysis. Apicolysis, as shown in my cases, can be trusted to control hemoptysis. A secondary thoracoplasty can be performed, if necessary, at a later date on the side on which apicolysis was done.

When the cavities are situated lower than the third rib, pneumothorax is a better procedure. Although the percentage of cures obtained with thoracoplasty is higher than with pneumothorax, the early and late mortality of extensive thoracoplasties and the deformities left by it demand a serious previous trial of pneumothorax. In cases of failure of pneumothorax to collapse the cavity because of the presence of adhesions, closed pneumolysis should be used. If this method also does not produce a satisfactory collapse of the cavities, thoracoplasty must be decided upon without further delay.

In the preceding lines I have tried to give the indications for thoracoplastic collapse of the tuberculous lung. It is evident that by enlarging the limits of operability we are bound to have a higher early and late mortality, but also, we shall have the satisfaction of having put on their feet a number of patients who would otherwise be doomed to certain death if treated by more conservative methods.

From the above it becomes obvious that in surgical statistics an exact description should be given of the form of tuberculosis and of the degree of extension of the disease in the patients operated upon. It would be easy to have a low postoperative mortality if we limited surgery to the "incipient cases" alone; but this would not decrease the mortality of our tuberculous patients as a whole. On the other hand, we should not forget that in tuberculosis, as in cancer, what counts is not only the percentage of mortality but also the percentage of cures. As Coffey said, surgeons who have a 20 per cent operative mortality in cancer of the colon choose their patients on a different basis than those who have a 30 per cent mortality.

RESULTS

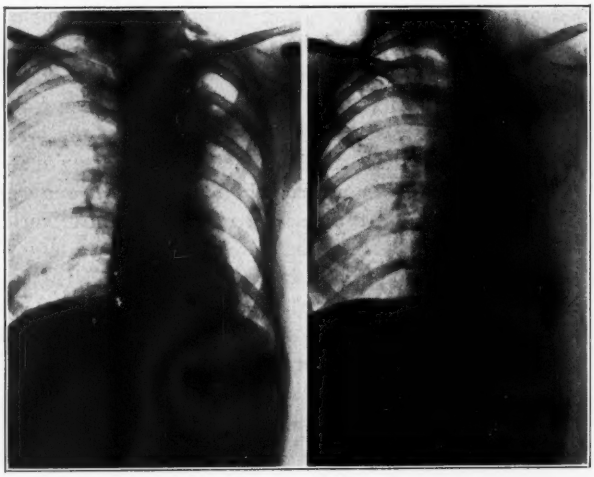
In the study of the results obtained in this series of 170 cases an exact definition of the meaning of the terms "cured," "improved" and "unimproved" as they are used here is necessary.

I consider as "cured" those patients whose sputum has become persistently negative (concentrated sputum examined on smear) after operation and who are able to perform a regular day's work without elevation of temperature of other signs of tuberculous toxemia. Persistence of slight cough and expectoration does not mean that the patient is not cured, as a number of these patients present a slight degree of residual bronchiectasis. Positive sputum at rare intervals but not exceeding Gaffky 1, does not mean that the treatment has failed, since most of our patients have chronic productive lesions on the other side which may give a positive sputum from time to time. Increase of weight and improvement in the general aspect of the patient are not considered as factors of importance in the classification of our operative results. The cases are numerous in which bed rest and good food alone produced a striking apparent improvement without any change in the lesions and in the prognosis as to the ultimate outcome.

It is difficult to give a precise definition of the term "improved" and more so of the term "unimproved." For the time being I consider as "improved" those patients with only occasional positive sputum, not above Gaffky 2, whereas before operation may have been Gaffky 5 to 10, and who are able to perform moderate work without presenting any fever or other signs of toxemia. In the long run, however, these cases pass under the headings of "cured" or of "unimproved." In fact in a number of my cases the sputum became persistently negative four, five or six months after thoracoplasty, as was already mentioned. In a very limited number, on the contrary, new cavities appeared in the contralateral and exceptionally in the operated lung. I have purposely avoided mentioning the physical and radiographic signs because they have given us rather unreliable information for the postoperative classification of our patients. Tracheobronchial sounds transmitted through the collapsed and atelectatic lung are often difficult to distinguish from bronchovesicular breathing, and it is generally impossible to discern in the radiograms with any degree of certainty whether a cavity is still present because of the bony lace which is formed by the irregularly regenerated bone.

The term "unimproved" has no other meaning than failure of the operation to cure the disease. To all intents and purposes these patients can be placed in the column of "late deaths." With the exception of bilateral cases in which only one side was operated upon the number of unimproved cases must be very small, and our efforts should tend to reduce it as much as possible even with danger of increasing the immediate mortality. Surgical treatment in tuberculosis of the lung must follow the same laws as in cancer; the operation must be radical in order to give to the patient all possible chances for a definite cure. An example will illustrate this statement. A patient,

C. G., white female, aged twenty-nine years, had had a left thoracoplasty in another hospital two years previous to her admission to Seaview Hospital, which did not produce any improvement. Cough and expectoration and tuberculous laryngitis with aphonia remained the same as before operation and the sputum was Gaffky 5 to 8. The length of the resected segments could not have been more than 2 cm. or 3 cm., as is shown by a close examination of an x-ray picture taken on admission (Fig. 21, *A*). Traces of the consolidation of the resected segments are clearly visible close to the vertebrae, similar to the ones found after fracture of the ribs. The chest was not collapsed and a large cavity was present in the left apex. This case certainly falls in the class of cases of which Fishberg says in his text-



A. *B.*

Fig. 21.—Case C. G. Incomplete collapse due to faulty technic (*A*). No improvement had followed that operation. A second thoracoplasty was performed two years later (*B*) producing a perfect clinical result. Sputum persistently negative.

book on tuberculosis: "If I could eradicate the residual stigmata of the surgical operation, the scar and the deformity and then have the patients examined by the physician and thoracic surgeon who favor thoracoplasty strongly, they would urge them to submit to thoracoplasty." That is exactly what I did in this case; a real thoracoplasty was performed upon her (190 cm. of ribs were resected, Fig. 21, *B*), and the patient has been bacilli free since that time and is cured of her tuberculous laryngitis. An interesting feature is that this patient was operated upon in the service of Dr. Fishberg on November 12 and December 3, 1930; the case was reported in a recent paper of Wiener and Fishberg (p. 346, Case 8) as illustrating the inability of thoraco-

plasty to cure tuberculosis. I mentioned this case because it gives the key to the explanation of the skepticism of these authors as to the efficiency of thoracoplasty.

DIVISION INTO GROUPS

The 170 cases studied here are not picked cases; they represent all the cases operated upon by me and my staff at Seaview and Metropolitan Hospitals of the city of New York from 1931 to 1933 without any exceptions or omissions. The material at these two hospitals is quite different. At Metropolitan the patients are transferred to the tuberculous service from the medical wards of this hospital or from other general hospitals of the city; the majority represent far advanced or acute cases, a number of which were first admitted to the medical wards with the diagnosis of acute bronchopneumonia or lobar pneumonia. On the contrary Seaview is a hospital for tuberculous patients to which patients are sent from the tuberculosis clinics of the Health Department of the city of New York and from other hospitals through the admitting office of the Department of Hospitals. The majority of these patients represent chronic cases. Therefore, often in the following tables a separate table of the respective results of each of these hospitals will be given. The separation into three groups is based upon their chronologic order and upon the technics used.

First Group.—Eighty-four cases operated upon from July, 1931, to March, 1932.

Endotracheal anesthesia was used. Extensive thoracoplasties were performed on this group with removal of from five to seven ribs in one stage. In the first stage the upper ribs were resected. Duration of operation was from thirty-five to fifty-five minutes. Endotracheal anesthesia and gas oxygen ether combined with bronchial suction were used. A limited number of cases were operated under regional anesthesia.

Second Group.—Forty-three cases operated upon from April, 1932, to June, 1932. The same technic as above was used with the difference that avertin basal anesthesia was used in these cases, combined with gas oxygen endotracheal anesthesia. No ether was given.

Third Group.—Forty-three cases operated from January, 1933, to November, 1933. Avertin anesthesia combined with endotracheal gas oxygen anesthesia. Endotracheal tube was used selectively and only when the amount of sputum in twenty-four hours was above 15 c.c. All cases of this group were operated upon by the modified thoracoplastic technic described above.

Because of the similarity of the technic used in the first two groups the results obtained in them will be considered together. The results obtained in the third group will be given separately.

1. General Results.—(Tables I and II.) The results of the first two groups were different from the results of the third group. In the first two groups the mortality was 23.6 per cent whereas in the third group it was 4.7 per cent (Table I). The causes of this discrepancy are: the simpler and more rapid technic and the different human material we were dealing with in the third group. The two first groups comprise the patients operated on in both institutions, Metropolitan and Seaview Hospitals, whereas all the patients of the third group were at Seaview Hospital. This is clearly shown in Table II, where the mortality of patients from Metropolitan was 34.2 per cent, whereas at Seaview it was 14.3 per cent.

TABLE I

	CASES	CURED	PER CENT	IMPROVED	PER CENT	UNIMPROVED	PER CENT	DEATHS	PER CENT
1st and 2nd Groups	127	65	51.2	19	14.9	13	11.2	30	23.6
3rd Group	43	31	72.1	8	18.6	2	4.6	2	4.7
Total	170	96	56.5	27	15.8	15	15.8	32	18.8

TABLE II

HOSPITAL	CASES	CURED	PER CENT	IMPROVED	PER CENT	UNIMPROVED	PER CENT	DEATHS	PER CENT
Metropolitan	38	14	36.8	7	18.4	4	10.5	13	34.2
Seaview	132	82	62.1	20	15.2	11	8.3	19	14.3
Total	170	96	56.5	27	15.8	15	8.3	32	18.8

On the other hand it is interesting to notice that the percentages of improved and unimproved cases have been almost the same in both hospitals, that is 18.4 per cent and 10.5 per cent against 15.2 per cent and 8.3 per cent, although the percentages of cures were very different, i.e., 36.8 per cent at Metropolitan against 62.1 per cent at Seaview. In the third group although the percentage of cured cases rose to 72.1 per cent, the percentage of improved remained the same, whereas of the unimproved it fell to 4.6 per cent. These figures show that extensive thoracoplasties may be accompanied by high mortality, especially in advanced cases but also that the percentage of cures is high compared to the improved and unimproved cases. This high mortality, however, was corrected in the third group by multiplying the stages without decreasing the extent of the resected bony skeleton. The mortality in this group was decreased and the percentage of cures considerably increased (72.1 per cent against 51.2 per cent).

2. Results According to the Distribution of the Disease.—In Tables I and II no distinction has been made between cases with unilateral and bilateral lesions. In the following I shall study separately: (1) unilateral cavities in the lung; (2) bilateral lesions, i.e., caseous pneumonic form in one lung and exudative or proliferative lesions in the other lung; (3) cavities in both lungs (Table III).

TABLE III

RESULTS ACCORDING TO THE NATURE AND DISTRIBUTION

NATURE AND DISTRIBUTION	NO. CASES	RESULTS			
		CURED	IMPROVED	UNIMPROVED	DEATHS
First and Second Groups					
A. Unilateral. Cavities.	44	24 54.5%	7 16.0%	4 9.0%	9 20.5%
B. Bilateral. Cavities in one lung exudative or productive in the other.	61	39 64.0%	10 16.4%	3 5.0%	9 14.5%
C. Bilateral. Cavities in both lungs.	22	2 9.0%	2 9.0%	6 27.3%	12 54.5%
Third Group					
A. Unilateral. Cavities (caseous pneumonic).	20	15 75.0%	4 20.0%	1 5.0%	0%
B. Bilateral. Cavities in one lung exudative or productive in other.	20	15 75.0%	3 15.0%	1 5.0%	1 5.0%
C. Bilateral cavities in both lungs.	3	1 33.3%	1 33.3%		1 33.3%
Total (3 Groups)					
A	64	39 (61.0%)	11 (17.2%)	5 (7.6%)	9 (14.0%)
B	81	54 (66.6%)	13 (16.0%)	4 (4.9%)	10 (12.3%)
C	25	3 (12.0%)	3 (12.0%)	6 (24.0%)	13 (52.0%)
Total	170	96	27	15	32

In the first and second groups the mortality was lowest in the bilateral cases in which exudative or productive lesions were present in the contralateral lung (14.5 per cent) and highest in the bilateral caseous pneumonic cases (54.5 per cent). The same was shown in the third group (5 per cent versus 33.3 per cent). This fact clearly shows the severity of prognosis in the bilateral caseous pneumonic cases; furthermore it explains the higher mortality of the statistics of surgeons who operate upon such cases.

Another fact shown by this table is again the significance of a simpler and shorter technic. In the unilateral cases of the first and second groups in which five to seven ribs were resected in the first stage and the duration of the operation was from thirty-five to fifty-

five minutes the mortality was 20.5 per cent; in the third group in which only three ribs were resected and the operation lasted from eighteen to thirty minutes the mortality was reduced to naught. This fact emphasizes the necessity of avoiding complicated and prolonged operation. On the other hand, resection of the total length of the three upper ribs has decreased failure to collapse the cavities in unilateral and bilateral cases as shown by the small number of unimproved cases; 9.0 per cent and 5.0 per cent in the first and second groups, and 5.0 per cent and 5.0 per cent in the third group.

A further study of this table emphasizes the small influence of the presence in the other lung of chronic productive lesions upon the final results of treatment. In the first and second groups the mortality in these cases was even smaller than of the strictly unilateral caseous pneumonic cases and in the third group it was the same. This fact shows the necessity of indicating in statistical studies of surgical treatment of pulmonary tuberculosis the form of the disease of the operated cases; otherwise it is impossible and useless to compare statistics of different surgeons. It is evident that surgeons who limit their operative indications to chronic productive cases only have a low mortality but have also performed unnecessary operations.

TABLE IV

RESULTS ACCORDING TO THE DISTRIBUTION OF THE DISEASE AND THE STAGES OF THORACOPLASTY

NATURE AND DISTRIBUTION OF DISEASE	NUMBER OF CASES	STAGE OF THORACOPLASTY				RESULTS			
		1	2	3	4	CURED	IMPROVED	UNIMPROVED	DEATHS
First and Second Groups									
Unilateral cavities	44	13				6(46.0%)	1	1	5(38.5%)
			30			17(38.6%)	6	3	4(9.0%)
				1		1			
Bilateral. Cavities in one lung, exudative or chronic productive in other	61	9				5(55.5%)	2		2(22.2%)
			45			28 (62.2%)	8	3	6(13.3%)
				4		3			1
					3	3			
Bilateral. Cavities in both lungs	22	11						4	7(63.6%)
			10			2(20.0%)	1	2	5(50.0%)
				1			1		
Third Group									
Unilateral cavities	20	3				2(66.6%)	1		0%
			15			11(73.3%)	3	1	0%
				2		2			
Bilateral. Cavities in one lung, exudative or chronic productive in the other	20	4				3(75.0%)	1		0%
			15			11(73.3%)	2	1	1(6.1%)
				1		1			
Bilateral. Cavities in both sides		2				1(50.0%			1 (50.0%)
			1				1		

The high mortality in the unilateral cases in the first and second groups is due, I believe, to the fact that patients with large cavities, even unilateral, stand extensive operations badly. Bilateral cases (with exudative or chronic productive lesions in the other lung) but with smaller cavities in the caseous pneumonic have shown a better resistance, although they may have appeared to be more advanced cases. For this reason the "quantitative" classification of the National Tuberculosis Association is less helpful in the choice of cases for surgical treatment than the "qualitative" classification of Ornstein, Ulmar and Dittler.

That patients with large cavities exhibit poor resistance to prolonged and extensive operation is clearly shown by the fact that in the first and second groups of patients, in whom five to seven ribs were resected at the first stage, the majority of deaths followed the first stage. Unilateral caseous pneumonic cases as well as bilateral cases (caseous pneumonic with exudative or productive lesions in the contralateral lung) showed respectively 38.5 per cent and 22.2 per cent mortality after the first stage as against 9.0 per cent and 13.3 per cent after the second stage (Table IV).

3. Results in the Different Stages of Thoracoplasty.—The fact that unilateral cases present higher mortality after first stage (38.5 per cent) than bilateral cases (22.2 per cent) is again a proof that mortality depends upon the extension of the caseous pneumonic lesions and not upon the amount of the productive or exudative changes. It is really surprising and encouraging how well patients with large apical cavities can stand subsequent stages after the main cavities have been completely or greatly collapsed. I do not believe that this is due to the increase of the so-called "resistance" of the patient. I have been unable thus far to find any clear and comprehensive definition of the factor "resistance" which occupies such a predominant place in speculations and discussions on the mechanism of cure of pulmonary tuberculosis. The same can be said for "immunity" and "compensation of the lung," a term recently coined by Pottenger. This tendency of trying to explain things which we do not know by terms that we understand even less, is greatly responsible for the confusion of our ideas upon the treatment and mechanism of cure of this disease. It would seem more rational to consider that following closure of the apical cavities by a first-stage thoracoplasty, less toxic material is produced by the tubercle bacilli contained in the cavity so that the patient is less toxic at the second stage than at the first. The mortality following second stages in both unilateral and bilateral cases was considerably lower in all groups than that following first stages. In unilateral cases the mortality was in the first and second groups, 38.5 per cent following first stage and only 9.0 per cent following second stages. In bilateral cases (caseous pneumonic and

exudative or productive in the other lung) the mortality fell from 22.2 per cent in first stages to 13.3 per cent in second stages. In the third group there was a less marked difference in the mortality following first and second stages because of the very low mortality of this group as a whole. Second stages were performed from two to four weeks after the first stages; it is difficult to believe that "resistance" or "immunity" was built up in such a short time especially as the same phenomenon was observed in bilateral caseous pneumonic lesions. I think that a simpler explanation and one more in agreement with operative results in other toxic diseases would be more acceptable. It is well known that any elaborate operation, comparable to a first-stage thoracoplasty, upon a patient with intestinal obstruction gives a very high mortality, whereas the same operation performed two or three weeks after a colostomy has decreased the tonicity of the patient, gives a greatly diminished mortality. In bilateral caseous pneumonic lesions, collapsing of one side does not eliminate the source of bacilli and toxic material; therefore the mortality is almost as high after the second stage as after the first stage; on the contrary with unilateral cavities, with or without productive lesions in the other side, collapse of the cavities decreases the toxicity of the patient and acts much as a colostomy in the case of intestinal obstruction. It is this conception which has led me to modify my technic. The results obtained in the third group are in favor of the soundness of this hypothesis.

4. Results According to Age.—(Table V.) The age of the patient has an important influence both upon the curability and upon the mortality. In patients between ten and twenty years of age we had 71.4 per cent cures, 14.2 per cent improvement, none unimproved, and 14.2

TABLE V

RESULTS ACCORDING TO AGE

AGES	CASES	CURED	IMPROVED	UNIMPROVED	DEATHS
10 to 20 years	28	20	4	0	4
	16.4%	71.4%	14.2%		14.2%
20 to 30 years	72	42	12	7	11
	42.3%	58.3%	16.8%	9.6%	15.3%
30 to 40 years	56	28	9	7	12
	32.9%	50.0%	16.1%	12.5%	21.4%
40 to 50 years	14	6	2	1	5
	8.3%	42.8%	14.3%	7.1%	35.7%
Total	170	96	27	15	32

per cent mortality. If we add together the cured and the improved, we have 85.6 per cent operative successes. On the contrary, between forty and fifty years of age, I had only 42.8 per cent cures, 14.3 per cent improved (57.1 per cent good results) and the mortality rose to 35.7 per cent. Between twenty and thirty years the percentage of

cures was 58.3 per cent and mortality 15.3 per cent; between thirty and forty years of age the cures were 50.0 per cent and mortality was 21.4 per cent.

These figures show clearly that cures decrease whereas mortality rises with age. This is of special importance when we deal with tuberculosis in young girls between fifteen and twenty-five years of age, in whom the disease runs a particularly rapid course. Our youngest patient was a girl of twelve years with advanced caseous pneumonic tuberculosis in the left lung. A three-stage thoracoplasty was performed upon her, with resection of eleven ribs (135 cm.); she made an uneventful recovery; a scoliosis of a moderate degree developed later, which I hope will be checked by the use of orthopedic braces.

Our oldest patient, who was forty-nine years of age, died. By multiplying the stages in patients above forty-five years of age we can carry through the operation successfully, although at present the mortality is still such that great care should be taken in the choice of these patients.

5. Results According to Sex.—(Table VI.) The sex of the patient had a decided influence upon the operative results. Females withstood the operation much better than males. Both mortality and morbidity were lower and the percentage of cures was higher. This may partly be due to the fact that females accepted the operation much easier and in earlier stages of the disease than male patients; this had a marked influence on the quantity and quality of the female operative material. Incidentally this psychologic factor is of real importance and should not be neglected especially at the beginning of surgical work in a sanatorium, where the number of patients accepting the operation will greatly depend upon the success or failure of the first attempts.

TABLE VI

RESULTS ACCORDING TO SEX

SEX	NUMBER	CURED	IMPROVED	UNIMPROVED	DEATHS
Males	64	31	11	6	16
		48.5%	17.1%	9.4%	25.0%
Females	106	65	16	9	16
		61.3%	15.0%	8.5%	15.0%
Total	170	96	27	15	32

Table VI gives the results obtained in male and female patients irrespective of age and race. The total number of female patients (106) represented almost two-thirds (62.3 per cent) of all patients. The percentage of cures was higher in females (61.3 per cent) than in males (48.5 per cent), and mortality much lower, 15.0 per cent as against 25.0 per cent in males.

6. Results According to the Operated Side.—(Table VII.) One finds in the literature a rather widespread belief that thoracoplasties on the

right chest are accompanied by a higher mortality than thoracoplasties on the left side. The explanation presented is that compression of the organs on the right side of the chest is more dangerous than on the left side, as the venae cavae and the right auricle are more compressible organs than the aorta and the left heart.

TABLE VII

STATISTICS ACCORDING TO THE OPERATED SIDE

SEX	SIDE	NUMBER	CURED	IMPROVED	UNIMPROVED	DEATHS
Males	Right	32	16 50%	6 18.7%	3 9.4%	7 21.8%
	Left	32	15 46.8%	5 15.6%	3 9.4%	9 28.1%
Females	Right	36	21 58.3%	7 19.5%	4 11.1%	4 11.1%
	Left	70	44 62.8%	9 12.8%	5 7.1%	12 17.1%
Males and females	Right	68 (40%)	37 (54.4%)	13 (19.2%)	7 (10.3%)	11 (16.1%)
Males and females	Left	102 (60.0%)	59 (57.8%)	14 (13.7%)	8 (7.8%)	21 (20 6%)

The results presented here do not bear out this statement. Table VII gives an analytical study of the results obtained following right and left thoracoplasties, separately for males and females and together for both sexes. In all instances the mortality was higher on the left than on the right side. In males it was 21.8 per cent on the right and 28.1 per cent on the left, in females 11 per cent on the right and 17.1 per cent on the left. In all right cases, male and female, mortality was lower on the right side (16.1 per cent) than on the left (20.6 per cent). Also the percentages of cured cases in females and in the total results were higher in operations upon the left (females 62.8 per cent, total 57.8 per cent) than upon the right side (females 58.3 per cent, total 54.4 per cent). Only in male patients were cures slightly more numerous on the right (50 per cent) than on the left (46.8 per cent).

The number of cases on the left was 60 per cent of the total number of patients.

7. Results in Colored Patients.—(Table VIII.) It is the general belief that pneumothorax yields less satisfactory results and higher mortality in colored than in white patients. It was therefore of interest to check the results of our thoracoplasties in colored cases. Thirty-three colored patients were operated upon, 15 males and 18 females. The total mortality was 21.2 per cent, slightly lower in males (20.0 per cent) than in females (22.0 per cent), and only slightly above the total average mortality in these series (19.8 per cent). Mortality according to the operated side was again higher on the left (23.5 per cent) than on the right side (18.7 per cent).

In the third group of my cases there were six colored patients, 2 males and 4 females. None of these patients died. Three of them were cured (50.0 per cent), one was improved (16.6 per cent), and 2 were unimproved (33.3 per cent). The above mentioned facts speak in favor of the conception that predominance of more severe forms of pulmonary tuberculosis in colored patients is due more to their low standards of living which expose them to massive tuberculous infections rather than to lower racial resistance to the tubercle bacilli. In this series colored patients showed no differences from white patients with similar lesions and responded to treatment in an identical way.

TABLE VIII

STATISTICS IN COLORED PATIENTS

SEX		CASES	CURED	IMPROVED	UNIMPROVED	DEATHS
I. General and According to Sex						
Males		15	4	3	5	3
			26.6%	20.0%	33.3%	20.0%
Females		18	9	2	3	4
			50.0%	11.1%	16.6%	22.2%
Total		33	13	5	8	7
			39.3%	15.1%	24.3%	21.2%
II. Sex and Operated Side						
			3	0	2	1
Males	Right	6	50.0%		33.3%	16.6%
			1	3	3	2
	Left	9	11.8%	33.3%	33.3%	22.2%
			5	1	2	2
Females	Right	10	50.0%	10.0%	20.0%	20.0%
			4	1	1	2
	Left	8	50.0%	10.0%	12.5%	25.0%
III. Operated Side						
Males and			8	1	4	3
females	Right	16	50.0%	6.8%	25.0%	18.7%
Males and			5	4	4	4
females	Left	17	29.4%	23.5%	23.5%	23.5%

8. Apical Lesions.—(Table IX.) These cases deserve to be studied separately because, as was already pointed out, it is in this group that the most brilliant results with thoracoplasty were obtained. This group comprises patients who presented cavities in one or both apices, which, at least in one lung, were located above a horizontal plane passing through the second intercostal space anteriorly. No cavities

TABLE IX

APICAL THORACOPLASTIES FOR APICAL LESIONS

DISTRIBUTION	CASES	CURED	IMPROVED	UNIMPROVED	DEATHS
		23	3	0	0
Unilateral	26	(88.4%)			
Bilateral	7	1(?)	1	2	3

should be present in the lung below this line. However, almost all of them presented more or less marked chronic productive lesions in the same or the contralateral lung or both. In all these cases pneumothorax was tried before and abandoned as unsuccessful. In 5 cases phrenicectomy had been done previously without benefit.

This group is composed of 33 cases. Twenty-nine had a three-rib upper thoracoplasty; in four cases four ribs were resected.

Twenty-six of these cases were unilateral, and 7 were bilateral. In the latter the lesion was strictly apical, at least in one lung. In 2 cases the cavities in the contralateral lung were limited to the apex; in the remaining 4 cases the lesions of the other lung extended lower than the middle third of the lung.

The postoperative mortality of the unilateral cases was nil. In 23 the cavities closed and the sputum remained persistently negative (88.4 per cent); 3 presented a marked and continued improvement (Gaffky 1 to 3).

The results in the 7 bilateral cases were as follows: One had a bilateral apical lesion, and a bilateral apical thoracoplasty was decided upon. After thoracoplasty on one side the patient showed a marked improvement in the contralateral lung and the operation was postponed to a later date.

One, after apical thoracoplasty on one side, had a successful selective pneumothorax in the contralateral lung which succeeded in closing the cavity. The sputum, however, is still occasionally positive. An apical thoracoplasty will be performed on that side at a later date.

Three have remained stationary and 3 died with extension of the disease.

The results obtained in apical cavities with partial thoracoplasties have been very rapid and consistent. In 16 of the 27 cases tubercle bacilli disappeared from the sputum within three weeks following operation. In 9 there was no positive sputum at all following operation. In the remaining 11 the sputum became negative within from three to seven weeks after operation. Only in one recent case has the sputum again become positive.

9. Analysis of Deaths.—(Table X.) All deaths were considered as being related to the operation unless it was absolutely evident that they were due to specific disease having no connection with pulmonary tuberculosis and in these cases only in so much as the course of both the thoracoplasty and the pulmonary lesion could not be incriminated.

As previously mentioned, the time elapsed between operation and death is not considered as a factor sufficient to determine the relation between operation and death. In fact, it is certain that in a patient who died six months after operation from an infected operative wound death should be considered as an operative death. On the

contrary a patient may have died three weeks after operation without death being due to the operation. Such was the case of a woman thirty-five years of age who presented mild symptoms of a toxic goiter. The wound had healed perfectly and the sputum had become negative. Three weeks after operation, when getting out of bed, she developed acute symptoms of thyrotoxicosis and died within two hours.

TABLE X

ANALYSIS OF DEATHS

Operative deaths	1. *Early operative deaths:*		
	Acute anoxemia and shock (within 48 hours)	8	
	Tuberculous pneumonia (within 2 to 5 days)	2	
	Mediastinal flutter (within 2 to 4 days)	3	
	Spontaneous pneumothorax (3rd to 5th postoperative day)	2	
			15
	2. *Deaths related to the operation:*		
	Wound infection (3, 7, 11 days and 3 months postoperative)	4	
	Secondary infection of pneumothorax cavity (32 days)	1	
	Cerebral embolism (24 hours and 33 days)	2	
	Toxic hemolytic jaundice (tuberculin shock) (8 days after operation)	1	
			8
	3. *Extension of tuberculosis:*		
	8 days (acute miliary)	1	
	1 month postoperative	1	
	2 months postoperative	2	
	6 months postoperative	1	
			5
Nonoperative deaths	4. *Deaths not related to operation:*		
	Diabetes (2 months postoperative)	1	
	Common duct obstruction (3 months postoperative)	1	
	Streptococcic infection right arm (3 months postoperative)	1	
	Thyrotoxicosis (3 weeks postoperative)	1	
			4
	Operative deaths	23	
	Percentage	13.5	
	Percentage of operations	6.1%	

It is more difficult to decide in cases in which death was due to extension of the disease (bronchogenic or hemotogenous) whether or not it should be attributed to the operation. I think that so long as we do not know what the influence of traumatism of the operation on the evolution of the disease may be we should attribute death to the operation, especially when sputum had remained positive and cavities were not closed, even when death occurred after more than six months following thoracoplasty. At any rate these cases are manifestly operative failure, and no one could have predicted with

absolute certainty that a given individual case would not have been cured spontaneously without operation. Almost anything may happen in the evolution of a tuberculous case.

Similar considerations hold for deaths due to cerebral embolism, even when this complication occurs as late as a month after operation. In one of my cases a colored woman of thirty-five years with Wassermann plus 4, an embolism occurred three weeks after operation when the wound was completely healed. She died suddenly with all the symptoms of cerebral embolism. Another patient, a white male, forty-five years of age, was found dead in bed thirty-one days after operation, fifteen minutes after having talked with the interne and while apparently in good condition. However, since it is difficult to exclude any relation between embolism and the operation, I do not think that we have the right to consider these deaths as unrelated to the operation.

Thus, of the 32 deaths in my cases, I class 23 (giving a general mortality of 13.5 per cent) as due to operation, of which 5 (2.9 per cent) were due to extension of tuberculosis. Only 4 (2.3 per cent) were considered as having no relation to operation. Thus my total operative mortality in these 170 cases was 13.5 per cent, including deaths due to extension of the disease. The mortality reported in 307 operations performed upon these cases was 6.1 per cent. The mortality unrelated to the operation reported in the cases was 2.0 per cent. A more detailed report of the percentages of different complications is given in Table X.

Morbidity.—There are three principal sources of postoperative morbidity: anoxemia, bronchial obstruction, and infection of the wound. Under the heading of complications, I have given the means by which I have endeavored to present postoperative morbidity.

Resection of a limited number of ribs at a time proved to be the best way for preventing anoxemia and mediastinal flutter. Short duration of the operation, gentle handling of the tissues, adequate hemostasis and strict asepsis are the most efficient means for preventing wound infection. Endotracheal anesthesia combined with bronchial suction in patients expectorating over 15 c.c. of sputum in twenty-four hours has reduced bronchial stasis and practically eliminated its corollaries, i.e., postoperative atelectasis, pneumonias and bronchopneumonias. Postoperative vomiting and abdominal distention and in considerable measure postoperative shock have been successfully controlled by intravenous injections of hypertonic saline solution. Prolonged use of an O_2 and CO_2 (10 per cent) mixture administered by nasal catheter has been of great help, during the forty-eight hours following operation, to overcome anoxemic shock.

Until recently I have had a rather high percentage of wound infections. Four patients died because of wound infection. In the last

group, however, 86 per cent of the cases showed primary healing or a slight infection limited to the subcutaneous tissue. But even in the third group there were 12 per cent of rather severe infections. This is a high percentage, and I hope that I shall be able to reduce it substantially in the future.

I am convinced that morbidity and mortality due to spread of the disease can be reduced still further by operating during the surgical phase, par excellence, of the disease, that is when the lesions are still limited to the apices. By operating at this stage and by using a rapid and simple technic and by neglecting none of the above mentioned means for preventing complications, such as anoxemia or bronchial stasis, we shall certainly be able to lower further our postoperative mortality and to decrease the number of "advanced cases." However, so long as advanced cases exist, I feel that we have not the right to refuse them any possible chance for cure, even if this conduct should increase our postoperative mortality. After all human life is worth while saving even if our statistics look less brilliant.

CONCLUSIONS

1. One hundred and seventy cases of thoracoplasty for pulmonary tuberculosis are presented; upon these patients 307 thoracoplastic operations were performed. These cases represent all patients operated on by me and my staff from 1931 to 1933 at Metropolitan and Seaview Hospitals of the city of New York.

2. The evolution of my views and of my technic is presented.

3. A simplified technic is described.

4. Complications which followed operations have been studied in detail.

5. The indications for choice of patients, choice of procedure and choice of time for operation are described.

6. An analysis and a statistical study of the results obtained are given. The influence of the clinical and pathologic form of the disease, of its distribution in the lung and of sex, age and race upon the operative results has been studied.

7. Special emphasis is placed upon the high percentage of curative results which can be obtained by operating on lesions still limited to the apex. It is shown that in these cases, with limited apical thoracoplasty, the operative mortality is almost nil whereas the proportion of "cures" exceeds 80 per cent.

8. Special stress is laid upon the necessity of thoracic surgeons following a "qualitative" and not a "quantitative" classification of pulmonary tuberculosis. The help of such a classification in the choice of patients, procedure and time of operation and especially in a judicious appraisal of the results obtained, is shown.

9. The cases of death have been studied. The cases of early postoperative and late morbidity are reported.

10. The necessity of a close cooperation between phthsiologists and thoracic surgeons is shown. Only constant teamwork between surgically minded medical men and medically and physiologically minded surgeons, guided by the facts alone and eliminating any stubborn conservatism or overenthusiastic radicalism, will permit a completion of this new and promising method of treatment of pulmonary tuberculosis.

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PHRENICECTOMY AS A TEST OPERATION*

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FOR many years Sauerbruch and other surgeons who have followed his teaching have recommended phrenicectomy to test the resistance of the opposite lung and to estimate its ability to stand up under a contemplated thoracoplasty. This practice presupposes that the lesser operation throws an increased fuctional burden upon the diseased portions of the better lung and that this burden is comparable to that imposed by a thoracoplasty. It is my belief that this teaching is based upon a misconception of the manner of action of the two operations. In the first place there is considerable evidence that phrenicectomy relaxes and exerts a favorable influence upon disease in the contralateral as well as upon that in the homolateral lung; and in the second place, even were this not the case, any slight alterations occasioned by the smaller operation could give no more idea of the opposite lung's ability to withstand the major procedure than could a gentle breeze the ability of a building to endure a hurricane.

I am here chiefly interested in supporting the contention that phrenicectomy relaxes and exerts a favorable influence upon disease in the opposite lung. Both theoretical conceptions and clinical observations support this view. In the first place, as was shown first by Schnippenkotter[1] and later by my own experiments,[2] paralysis of the hemidiaphragm is compensated for chiefly by an increased action of the ribs upon the homolateral side. In the second place, and this consideration is more important, it must be recognized that in the presence of a mobile mediastinum, limited relaxation of any part of the thoracic wall acts selectively upon the diseased portions of both lungs. In these the elastic tension is greatest, and for this reason they contract, even though they be distant from the site of the collapse, before the normal portions of the lungs. A mobile mediastinum permits the relaxation to affect the disease in the opposite lung as well as that in the homolateral lung.

This theory is borne out by the following clinical observations. In 1932, Dr. Schlack, Dr. Marx and myself[3] compared the results in a group of patients submitted to phrenicectomy with those in a comparable group who had had no collapse therapy. This study showed that after phrenicectomy not only was disease less likely to develop in the opposite lung but that disease already there was less liable to progress and more likely to heal than in cases where the operation had not been performed.

*From the Edward Sanatorium, Naperville, Ill.
Received for publication, April 10, 1934.

Thoracoplasty cannot be compared to phrenicectomy in its action upon the other lung any more than a complete pneumothorax can be compared to a selective pneumothorax. Both thoracoplasty and complete pneumothorax collapse all of one lung, the functioning tissue as well as that not functioning, and both do therefore throw an increased burden upon the lung remaining. When the collapse is partial, as with low pressure pneumothorax and phrenicectomy, it is always selective, and when the mediastinum is not fixed is selective for the disease in both lungs.

Whether or not the contralateral lung will stand up after thoracoplasty is an important and difficult question. It is my belief that it can be solved best by one who has had much experience both with tuberculosis and with the operation. It is assumed that thoracoplasty will rarely be contemplated when there is a cavity in the better lung, and that the question will arise only when more or less widely scattered infiltrations are under consideration. As to the resistance of these, serial roentgenograms afford the most valuable information. The presence or absence of physical findings, while important, is not a reliable criterion. An early progressing lesion may produce no râles, while râles may be present over one well healed. If the serial roentgenograms show that the lesions, after showing progressive improvement, have remained stationary for many months, one can, if they are not too extensive, operate with a reasonable degree of safety. A phrenicectomy on the worse side may be used to further their contraction or a pneumothorax on the better, but the operation cannot be relied upon as a test of their resistance.

Another factor of importance in this connection is the extent of the involvement in the side to be operated upon. The increase in the strain upon the contralateral lung will be in proportion to the amount of functioning lung collapsed by the operation. If the diseased lung is already completely involved and functionless, the opposite one will already have assumed a maximum responsibility and can be little affected by the collapse. If, on the other hand, there is still much normal tissue on the affected side, its sudden collapse will throw an equally sudden increase in burden upon the other side.

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UNSUCCESSFUL PHRENICOEXAIRESIS*

Report of Fifteen Cases

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PHRENICOEXAIRESIS, although successful in the great majority of cases, occasionally fails in its object of producing total and permanent paralysis of the diaphragm. The causes of negative results are, first, avulsion of an insufficient length of the phrenic nerve, and, second, excision of some other nerve, or structure, which is mistaken for the main trunk of the nerve.

The method of producing paralysis of the diaphragm, originally proposed by Stuertz,[1] consisted in simple division of the phrenic nerve. It was discovered, however, that in a large proportion of cases, the procedure either did not result in paralysis, or that, sooner or later, a return of the normal function of the hemidiaphragm occurred. Walther[2] examined 26 patients operated on by Sauerbruch until 1914, and found that in more than 50 per cent, simple phrenicotomy had not completely paralyzed the hemidiaphragm, and that in 20 per cent of the remaining cases the normal function had returned more or less immediately after operation. As a matter of fact, the results proved so unsatisfactory that the procedure fell into more or less disuse until Felix[3] and Goetze[4] established the anatomic basis for the failures, by demonstrating that in a large proportion of cases there occur one or more accessory phrenic nerves, which are not eliminated by simple phrenicotomy, and maintain, or take over, the motor innervation of the hemidiaphragm after section of the main stem of the phrenic nerve in the neck.

The frequency with which accessory phrenic nerves occur has been variously estimated from investigations on cadavers, and from clinical findings. Felix[3] placed it at 20 to 30 per cent, and Sauerbruch[5] at 37.8 per cent, of all persons. Goetze,[4] in dissections of 25 phrenic nerves in 13 cadavers, found that simple phrenicotomy would have been unsuccessful in 68 per cent of these cases. Ruhemann[6] found accessory phrenic nerves in more than 50 per cent of 17 cadavers. Plenk and Matson,[7] in dissections of 112 phrenic nerves in 56 cadavers, found atypical formations of the nerve in 28 per cent. Aycock and Habliston[8] found accessory nerves which entered the main stem of the phrenic nerve below the usual site of operation in 65 per cent of 130 cadavers. Wirth and von Jaski[9] reported the presence of accessory

*From the Sanatorium of The Jewish Consumptives' Relief Society, Spivak, Colorado.
Received for publication, June 8, 1933.

nerves in 43 per cent of 600 operations, and Fisher[10] in 60 per cent of 36 operations. Campbell,[11] on the other hand, observed them in only 3 out of 31 cases, or about 10 per cent.

According to the anatomic studies of Felix,[3] Goetze,[4] Ruhemann,[6] and others, the junction of the accessory phrenic nerve with the main trunk occurs nearly always above the hilum of the lung. Rarely, a double or accessory nerve anastomoses with the main stem below the pulmonary root, and a few centimeters above the diaphragm. Ruhemann,[6] has collected 6 such cases from the literature (Haase in 1793, Luschka in 1853, Turner [2 cases] in 1874, Larkin in 1889, and Goetze in 1922). Salomon[12] reported a case in which the accessory nerve joined the main stem above the beginning of the terminal fibers in the diaphragm. Wirth and von Jaski[9] found accessory, or double phrenic nerves, which united with the main trunk immediately above the diaphragm, in 5 of their series of 600 cases.

To eliminate completely the accessory innervation of the diaphragm, two methods have been proposed. Goetze[4] believed that it could be accomplished by his so-called radical phrenicotomy, under the impression that the principal path of the accessory phrenic fibers is through the subclavian nerve, and that resection of a small portion of the latter in addition to simple phrenicotomy would suffice to produce total and permanent paralysis of the respective hemidiaphragm. Felix[3] and, subsequently, other investigators, however, have demonstrated that Goetze's operation eliminates only a small proportion of the varieties of accessory phrenic nerves, and, therefore, advocated avulsion, or exairesis of the nerve, as the most certain method of interrupting all the motor paths to the diaphragm. Both methods have their supporters and opponents. However, exairesis, according to Felix-Lebsche, has become the operation of choice, especially in this country, as being less dangerous and less time-consuming in its performance.

Since the hilum of the lung is approximately 10 to 12 cm. from the usual site of operation, it is agreed by nearly all observers that the avulsion of at least this amount is sufficient to insure interruption of all accessory fibers in the overwhelming majority of cases. Avulsion of less than 10 cm. must, therefore, be considered as equivalent to a simple phrenicotomy, with the possibility of failure in a certain proportion of cases.

In practice, exairesis of 10 cm. or more of the nerve is not always attainable. In a considerable number of cases the nerve tears off prematurely. Wirth and von Jaski,[9] in a series of 551 cases, had the following results:

Length of Nerve	*Number of Cases*	*Per Cent*
1- 5 cm.	86	15.6
5.5-10 cm.	121	22.0
11-20 cm.	127	23.0
21-42 cm.	217	39.4

In 105 cases reported by Davies,[13] 10 cm. and less were avulsed in 34.3 per cent, 10 to 15 cm. in 28.6 per cent, and over 15 cm. in 37.1 per cent. In Matson's[14] first 150 cases less than 10 cm. were avulsed in 29 cases, or about 19 per cent. Fisher[10] succeeded in complete avulsion of the nerve in 66.6 per cent of 36 cases; in only one case was the length less than 10 cm.

In our series of 174 cases the lengths avulsed were as follows:

Length in cm.	*Number of Cases*	*Per Cent*
2.5-5.5	18	10.3
6- 9	29	16.7
10-15	46	26.4
16-20	15	8.6
Over 20	66	38.0

IMMEDIATE FAILURE TO PRODUCE PARALYSIS

Considering the large number of cases of phrenicoexairesis reported in the literature, and in view of the anatomy and frequency of accessory nerves, it is noteworthy that only very few instances of immediate failures to produce paralysis of the corresponding hemidiaphragm, with avulsion of less than 10 to 12 cm. of the nerve, have been recorded. Jessen[15] reported one case with avulsion of 5 cm. of the nerve among 20 cases. Davies[13] stated that in his series of 105 cases there was no failure, with the possible exception of one case with resection of 2.5 cm. of the nerve, and in which the dome of the hemidiaphragm was obscured. Fisher[10] mentions that Bethune, in a series of about 200 cases, had never failed to secure paralysis of the diaphragm, even when only a few centimeters of the nerve were avulsed. Campbell,[11] on the other hand, failed to obtain paralysis in about 10 per cent of 31 cases.

The function of the hemidiaphragm was studied in 130 of our cases. In none of 35 cases in which less than 10 cm. of the nerve was avulsed did the operation fail to produce immediate paralysis, where the evidence was conclusive that a portion of the main stem of the phrenic had been resected. In one case, however, with avulsion of 10 cm. of the nerve, immediate paralysis failed to occur.

CASE 1.—F. R., left phrenicoexairesis August 23, 1932. The nerve was located in the normal position and torn off at 10 cm. Six days after operation, and on five subsequent fluoroscopies, during a period of nine months, the hemidiaphragm presented slightly restricted, but normal, motion. There was a slight rise of the hemidiaphragm at first, which later disappeared.

Immediate failure did not occur in any other of our cases with avulsion of 10 cm. or more of the nerve. It has, however, been observed. Naegeli and Schulte-Tigges[16] reported 2 cases in which, after successful exairesis of 20 to 30 cm., the hemidiaphragms retained the same mobility. O'Brien[17] mentions a case in which after a crushing operation and a subsequent avulsion of 22 cm., the hemidiaphragm was not paralyzed. No accessory nerve was found.

RESTORATION OF NORMAL FUNCTION

Return of normal function after an initial paralysis has been observed somewhat more frequently. Zadek and Sonnenfeld[18] were the first to report the observation, which they designated as surprising, of a case of phrenicoexairesis of three years' duration, combined with pneumothorax for two years, in which they found, in spite of the former high position of the hemidiaphragm with paradoxical motion, a return to its normal level with normal respiratory excursions. Three years later this condition had remained unchanged. In this case 14 cm. of the nerve had been avulsed, a length generally accepted as sufficient to interrupt the accessory innervation. Sonnenfeld[19] has reported another case which showed a spontaneous return of normal diaphragmatic function within ten months after exairesis of 10 cm. of the nerve, and previously demonstrable paralysis of the hemidiaphragm with a rise of 2 cm.

Since then, similar observations have been reported by other writers. Davies[13] mentions a case with avulsion of 11 cm. of the nerve. A rise of the hemidiaphragm with paradoxical motion occurred immediately and was also observed one month after operation, with recovery of the normal function six months later. Wirth and von Jaski[9] found normal diaphragmatic function in 14 of 170 cases reexamined one to five years after operation. The number of these cases decreased with increase in the length of nerve avulsed. Thus, it was found in 8, or 26.6 per cent, of 30 cases in which 1 to 5 cm. of the nerve was avulsed; in 3, or 9.3 per cent, of 32 cases in which 5.5 to 10 cm. was avulsed; and in 3, or 6.7 per cent, of 45 cases in which 11 to 20 cm. was avulsed. In the last 3 cases, 12 cm. had been avulsed. In no case in which more than 12 cm. had been avulsed was there a return of normal function. Among 185 cases, reexamined one to five years later, including cases in which there were no data about the lengths of the nerves avulsed, the function was found to be normal in 24, or about 13 per cent. Repeated x-ray controls after operation until the end of treatment showed complete paralysis.

Matson[14] stated that he had never observed a return of function when the avulsed nerve measured 10 cm. or more, and that with avulsion of less than this length, a return of diaphragmatic function can be expected in about 25 per cent of cases, if the accessory or communicating fibers have not been severed. He observed 11 cases over a period of from one to five and one-half years. In all of these the length avulsed was less than 10 cm., and in 4, less than 5 cm. A return of function was noted in only 3 cases, or 27.3 per cent, this occurring in less than six months. All of these presented a hemidiaphragmatic paralysis immediately after operation. In 8 of the 11 cases, the paralysis was still present one year later.

Moore[20] reports a case of avulsion of 10 cm. of the left phrenic nerve and resection of 1 cm. of the nerve to the subclavius. Immediately, and two months later, there was definite paralysis, and paradoxical motion. Nine months later there was paradoxical motion on sniffing, but an excursion of 3 cm. of normal motion on forced respiration.

Return of normal motion, after a temporary paralysis occurred in 4, or 11.4 per cent, of 35 cases of our series, in which less than 10 cm. was avulsed, compared with about 8.2 per cent in Wirth and von Jaski's[9] and about 27.3 per cent in Matson's[14] cases.

CASE 2.—M. S., right phrenicoexairesis March 15, 1932, with avulsion of 2.5 cm. of the nerve. Three days later there was noted paradoxical motion without a rise of the hemidiaphragm. On two subsequent fluoroscopies the hemidiaphragm was completely immobile. Three months after operation, normal restricted motion, without a rise, was found.

CASE 3.—P. E., right phrenicoexairesis November 25, 1929, with removal of 3 cm. of the nerve. Five days later there was a rise of 3.75 cm., with very slight paradoxical motion, of the hemidiaphragm. No further fluoroscopic observations were made until two years and eight months after operation, when slight paradoxical motion was still present. Seven months later the function of the hemidiaphragm was found to be normal, but restricted. The sniffing and Bittorf tests were negative. After reaching an elevation of 4.4 cm., seven months after operation, the rise gradually became less, and three years and three months after operation, when normal motion was first noted, the hemidiaphragm had returned to its preoperative level.

CASE 4.—D. B., right phrenicoexairesis March 1, 1932, with avulsion of 4 cm. of nerve, which was found in the normal position. On May 10, a rise of one and one-half interspaces with slight paradoxical motion was noted. Eight and one-half months after operation the function of the hemidiaphragm was found to be normal, but considerably restricted in its motion. The sniffing and Bittorf tests, however, were slightly to moderately paradoxical. The same condition was noted on four subsequent fluoroscopies until one year and three months after operation. The hemidiaphragm showed a rise from 4.4 to 5.6 cm., and the normal motion continued to be accompanied by definitely positive sniffing and Bittorf tests.

CASE 5.—F. F., left phrenicoexairesis July 21, 1931, with avulsion of 6.25 cm. of the nerve. Three and one-half months later there was a rise of 4 cm. with a moderate degree of paradoxical motion. Ten months after operation, the function of the hemidiaphragm had become normal, with complete disappearance of the elevation. Two months later the same condition was noted, with restriction of the normal excursions.

The restoration of normal motion in these cases can be explained only on the assumption that the lengths of the nerves avulsed were not sufficient to interrupt the accessory nerve fibers, which eventually took over the function of the main trunk of the phrenic nerve. Regeneration of the nerves, in the light of our present knowledge, cannot be accepted as a cause of the return of normal function. Even in simple

phrenicotomy the nerve stumps undergo so strong a retraction that the growing together of the severed ends cannot be considered as possible.

Return of normal function after avulsion of 10 cm. and more of the nerve occurred in 7, or 7.6 per cent of 92 of our cases.

CASE 6.—C. M., left phrenicoexairesis May 5, 1931, with avulsion of 10 cm. of the nerve. Subsequent fluoroscopies showed the hemidiaphragm to be paralyzed, with slight to moderate paradoxical motion. Ten months after operation there was noted normal motion with a respiratory excursion of about one interspace. The same condition was observed on three subsequent fluoroscopies until one year and four months after operation, except that normal motion became somewhat more restricted. The sniffing and Bittorf tests were negative. There occurred an elevation of 2 cm. which was probably due to contraction of the lung.

CASE 7.—B. A., left phrenicoexairesis November 11, 1930, with avulsion of 12.5 cm. of the nerve. There occurred a rise of 3.7 cm., which, however, had disappeared a year and a half after operation. No fluoroscopic examinations were made until two years and nine months after operation, when the hemidiaphragm presented normal motion, with negative sniffing and Bittorf tests. This persisted on six reexaminations until four years after operation. The hemidiaphragm shows an elevation of about 1.5 cm. which, however, is probably due to contraction of the lung.

CASE 8.—L. J., left phrenicoexairesis November 11, 1930, with avulsion of 12.5 cm. of the nerve. Two weeks later there was complete paralysis with a slight rise of the hemidiaphragm. Six months and one year after operation moderate paradoxical motion was noted. Two years after operation the motion of the left hemidiaphragm was found to be normal, but restricted. The sniffing and Bittorf tests were negative. There was no rise of the hemidiaphragm. At the last observation, six and a half months later, the same condition was noted.

CASE 9.—C. F., right phrenicoexairesis November 15, 1929, with avulsion of 15 cm. of the nerve. About one year later the hemidiaphragm presented normal respiratory excursions. Subsequent fluoroscopies until three years and five months had elapsed, showed completely normal function, with negative sniffing and Bittorf tests. After an initial rise of 4 cm., the hemidiaphragm returned to its preoperative position.

CASE 10.—D. M., right phrenicoexairesis September 13, 1932, with avulsion of 20 cm. of the nerve. Until six months after operation there was noted, at first, immobility, and, later, slight paradoxical motion of the hemidiaphragm, with slightly positive sniffing and Bittorf tests. The motion then presented a suggestion of a return to normal. Nine months after operation there were definitely normal respiratory excursions, with negative sniffing and Bittorf tests. The initial rise of about 2.5 cm. persisted.

CASE 11.—P. D., right phrenicoexairesis November 25, 1931, with avulsion of 22.5 cm. of the nerve. The hemidiaphragm showed an immediate elevation of 3.1 cm. which increased to 4.4 cm. after one year. At that time there was noted slight paradoxical motion. The sniffing and Bittorf tests were positive. Two months later the paradoxical motion was present, with a positive sniffing test and a very strongly positive Bittorf test. Two months later the hemidiaphragm was immobile on ordinary respiration but very strongly positive on the other tests. One year and six months after operation, the motion was of a slight but definitely normal character. The other tests had become only slightly positive. The elevation of the hemidiaphragm decreased from the maximum of 4.4 cm. to 2.5 cm.

CASE 12.—L. M., left phrenicoexairesis May 26, 1931, with avulsion of 31.25 cm. of the nerve. Until one year and eight months after operation the hemidiaphragm was immobile, with a rise increasing from 4 cm. to 5.6 cm. The sniffing test was positive, and the Bittorf test was very strongly positive. One year and ten months after operation these tests were still positive but there was a faint suggestion of normal motion, which, two months later, was definitely normal with disappearance of the paradoxical motion on the sniffing and Bittorf tests. The elevation of the hemidiaphragm was 5.3 cm.

Opinions regarding the length of nerve necessary to be avulsed to eliminate the accessory innervation vary somewhat. Aycock and Habliston[8] say that it is of the utmost importance to remove at least 11 cm. in order to secure the desired result. Felix,[3] Sachs,[21] Wirth and von Jaski,[9] and Schürch,[22] among others, consider that at least 12 cm. is necessary to interrupt all the accessory nerves which unite with the main stem above the hilum. Landé,[23] on the other hand, states that 12 to 20 cm. are required to accomplish it. The return of function in our cases in which 10 cm., 12.5 cm. (2 cases), and 15 cm. were avulsed must, therefore, be ascribed to the same cause as in cases with avulsion of shorter nerve lengths, namely, persistence of accessory innervation.

Return of normal function after avulsion of 20 cm., or more, of the phrenic nerve, as occurred in 3 of our cases (20 cm., 22.5 cm., and 31.25 cm.) is comparatively rare. Ernst[24] observed a patient in whom the whole nerve was avulsed, followed by a considerable rise of the hemidiaphragm with paradoxical motion. Sixteen months later, however, the diaphragm was found in the normal position, with normal motion. A satisfactory explanation which is applicable to all such cases cannot be given. According to all available evidence the twelfth intercostal nerve, the sympathetic innervation, and motor branches from the contralateral phrenic nerve, play no rôle whatever in this phenomenon. Unquestionably the motor innervation in these cases is transferred to other preexisting anomalous accessory or double phrenic nerves, which gradually take over the full function of the main nerve. Schulze[25] explained the restoration of normal motion in one of his cases, eight months after a successful exairesis, by regeneration of the subclavian nerve. Upon reoperation, he found the central stump of the phrenic nerve in the normal position. After avulsion of the subclavian nerve he obtained lasting paralysis.

FAILURE TO FIND THE PHRENIC NERVE

Complete failure to find the phrenic nerve has been reported by several writers. Wirth and von Jaski[9] experienced it in 3 out of 600 cases. Sachs[21] was unable to locate the nerve in 1 out of 163 cases at the first operation, and after searching for it for two hours at a subsequent reoperation, which was followed by a Horner's syndrome. Sultan[26] was unable to find the nerve in 1 out of 177 cases.

More frequently some other nerve or structure is mistaken for the phrenic nerve and avulsed, with failure to produce paralysis. This occurred in 3 of our cases.

CASE 13.—M. R., right phrenicoexairesis February 28, 1930. What was believed to be the main stem of the nerve was located at the median border of the scalenus anticus muscle. On attempting avulsion marked resistance was encountered. The peripheral end broke off, was located, and again broke, yielding about 3 cm. of the nerve. Fluoroscopy showed absence of paralysis and no rise of the hemidiaphragm immediately after operation, or during six and a half months of observation. Following the operation there developed drooping of the right side of the face and of the angle of the mouth, loss of expression, ptosis of the right eyelid with marked narrowing of the palpebral commissure, and contraction of the pupil to half the size of the left. Patient complained of numbness extending from the right ear forward to the cheek bone. Hyperesthesia was present above the right clavicle. The findings were those of a pronounced Horner's syndrome and a partial superficial facial palsy for which there did not appear to be any anatomic basis. The neurologic findings cleared up in about three weeks.

CASE 14.—S. L. C., right phenicoexairesis May 3, 1932. Nerve located in normal position. Traction resulted in immediate rupture, with removal of 2.5 cm. of the nerve. Immediately thereafter there developed a marked Horner's syndrome which persisted for several months. Nine days later, and on five subsequent fluoroscopies until one year after operation, the motion of the hemidiaphragm was normal. On May 23, 1933, another operation was performed. The incision was made about 2 cm. below the former incision. The phrenic nerve was located in the normal position without difficulty, and 17.5 cm. was avulsed. Eight days later the right hemidiaphragm showed a rise of over one interspace with paradoxical motion on quiet respiration and on the sniffing and Bittorf tests.

CASE 15.—A. V., admitted on September 13, 1931, with the history of a left artificial pneumothorax, induced January 5, 1928, and of a left phrenicectomy March 16, 1928. There was a complete collapse of the left lung. Fluoroscopy showed a slightly higher than normal position of the hemidiaphragm, with normal respiratory excursions and negative sniffing and Bittorf tests. This persisted after complete reexpansion of the lung. Inquiry revealed that 4.5 cm. of the nerve had been avulsed; that the nerve was very small, and broke easily. A roentgenogram two weeks after operation showed no change in the level of the hemidiaphragm. No fluoroscopic observations were made. The opinion was expressed that the nerve, which had been avulsed, was probably an accessory one. It was quite evident that whatever was done had no effect on the position and function of the hemidiaphragm. On account of increase of cough and expectoration after reexpansion of the lung, a second operation was performed on March 28, 1933, about five years after the first phrenicectomy.

There was no difficulty in locating the normal phrenic nerve in the usual position, and to avulse 15 cm. Fluoroscopy, nine days and again three months later, showed a rise of 3.5 cm. The hemidiaphragm had become immobile on ordinary respiration, but the sniffing and Bittorf tests were slightly positive.

In Cases 13 and 14, it was obvious that a branch of the sympathetic was mistaken for the phrenic nerve, as evidenced by the occurrence of a Horner's syndrome. In Case 15, it is probable that a strand of tissue of some kind instead of the phrenic nerve was removed. In Cases 14 and 15 it was conclusively proved by reoperation that the phrenic had

not been located the first time. Upon reoperation the nerves were located without difficulty in normal tissues, and 17.5 cm. and 15 cm., respectively, were avulsed, followed by paralysis of the hemidiaphragms.

Ernst[24] reported 4 cases which had been referred to him for repetition of the operation, in which at the first trial the nerves tore prematurely at 2 cm., 5 cm., 7 cm., and 10 cm., respectively, and the hemidiaphragms retained, or regained, normal mobility. At the second operation, the nerves were found in the typical positions and successful exairesis was performed in each case. Denk and Domanig[27] mention 3 cases referred to them in which the nerves were not found the first time, but were located without difficulty at a second trial. Fisher[10] reported a patient operated on, without producing permanent paralysis. A year later resection of 10 cm. of the nerve resulted in immediate immobilization and elevation of the hemidiaphragm.

Occasionally failure is due to anomalous positions of the nerve. Landé[23] had one negative result in 20 cases. What was believed to have been the main stem of the phrenic was found in the typical position. It was surprisingly thin and broke off after avulsion of 4 cm. of the nerve. This nerve, however, appears to have been an accessory nerve in an abnormal position. Lilienthal[28] reports a case in which after one unsuccessful attempt to locate the nerve, it was found, on a second trial, within the substance of the scalenus anticus muscle. In one case reported by Ernst[24] 4 cm. of what was mistaken for the phrenic nerve was avulsed without any effect; and in another case, the nerve was not found after a search for one hour. In both cases the nerves were found in abnormal positions at the second operation, and avulsion was followed by complete paralysis.

SUMMARY

1. Report is made of 15 cases of unsuccessful phrenicoexairesis.

2. Among 131 cases in which the lengths of the avulsed nerves were measured, and the function of the hemidiaphragms was observed by repeated fluoroscopies, immediate failure to produce paralysis was noted in 4 cases, and a return of normal function after temporary paralysis in 11 cases.

3. Immediate failure in 3 of the 4 cases was due to the resection of some other nerve or structure mistaken for the phrenic nerve, as proved by reoperation in 2 cases. In the fourth case, the failure was undoubtedly due to accessory innervation, which was not eliminated by avulsion of 10 cm. of the phrenic nerve.

4. Restoration of function of a previously paralyzed hemidiaphragm can also be explained only by the presence of accessory or double phrenic nerves, anastomosing with the main stem at various levels below the point at which the nerve tears off.

5. In view of the comparatively small proportion of failures, even with avulsion of only a few centimeters of the nerve, a protracted search for accessory nerves is not advisable.

6. In cases with immediate failure to produce paralysis, reoperation is indicated, especially when the evidence points to some other nerve or structure having been mistaken for the phrenic nerve or its main stem.

7. In cases of restoration of normal function after a successful phrenicoexairesis, a second trial is very rarely indicated.

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THROMBOSIS OF MAIN BRANCHES OF THE PULMONARY ARTERY*

With a Case Report and Review of the Literature

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OCCLUSION of the main branches of the pulmonary artery is of interest from the diagnostic as well as the etiologic considerations. Following experience with such a case, a search of the literature was made for information which might assist in making a diagnosis antemortem. In this survey it was found that such occlusion has been reported only rarely and that the diagnosis was not made before death.

It is probable that there is a definite symptom complex in primary thrombosis of one or more of the larger branches of the pulmonary artery, but an associated pathologic condition, such as cardiac disease, may make the interpretation of symptoms uncertain and difficult. It seems worth while to analyze the reported cases and to select the symptoms and signs which might assist in making, or at least in suspecting the diagnosis of the true pathologic state. The recognition of the condition is of importance, since life is compatible with a slowly progressing occlusion of a main branch of the pulmonary artery, and baffling symptoms may be present weeks or years.

No consideration has been given to embolic closure as seen postoperatively and postpartum, nor to more chronic closure of the smaller branches. Attention is given only to partial or complete occlusion of main branches of such duration that symptoms and signs are made manifest. Symptoms, signs and postmortem findings of the cases gathered from the literature are briefly presented in Table I.

CASE REPORT

A white housewife, forty-six years of age, was first seen on April 26, 1931, because of weakness of the left arm and leg, and severe headache.

Present Illness. (The husband supplied the history because of the patient's disorientation.) For three months there had been some distress referred to the right lower abdomen, which increased to definite pain in the past several weeks. On April 22, vomiting occurred, followed on the next day by severe headache which persisted two days. On April 25, a generalized convulsive seizure, lasting five minutes, occurred. This was followed by deep stupor which lasted seven hours. More than twenty-four hours later, as the patient attempted to get out of bed, it was found she had lost the use of the left arm and leg. There was also urinary retention. She complained bitterly of right-sided headache.

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Received for publication, April 4, 1934.

TABLE I

NUMBER	AUTHOR	AGE	SEX	DURATION OF SYMPTOMS	DYSPNEA	COUGH	HEMOPTYSIS	CHEST PAIN	NEUROLOGICAL SYMPTOMS AND SIGNS	CYANOSIS	EDEMA EXTREMITIES	CARDIAC SIGNS	PULMONARY SIGNS	POSTMORTEM FINDINGS			
														SITE OF THROMBUS	PULMONARY	CARDIAC	
1	Helie[1] (1837)	65	F	3 mo.	x	–	–	–	x	x	–	----	----	BM	----	E	
2	Kidd[2] (1856)	26	F	--	–	x	x	–	–	–	–	E	----	LL	----	E	
3	Blachez[3] (1866)	29	F	3 yr.	x	–	–	–	–	x	x	Systolic and diastolic murmur	----	RM	Infarcts	RVE	
4	Elbogen[4] (1884)	44	M	3 wk.	x	x	x	–	x	x	–	----	Emphysema	BM	Gangrenous infarct	RVE	
5	Jurgenson[5] (1899)	60	M	1 yr.	x	–	–	–	x	x	–	RE	Emphysema	BM	Edema	----	
6	McPhedran and McKenzie[6] (1903)	55	M	14 da.	x	x	x	x	–	–	x	E	Râles rt. base	RM	Infarction hemorrhagic	E	
7	Monckeberg[2] (1907)	56	M	--	?	?	?	?	?	?	?	?	?	RM	----	----	
8	Stadelmann[7] (1909)	27	M	Weeks	x	–	x	–	–	x	x	Mitral stenosis and insufficiency	----	BM	Infarcts	E	
9	Kraus[7] (1909)	30	M	Several mo.	x	–	–	x	–	x	–	RE	Edema in attacks	RM	Edema	----	
10	Billings[8] (1921)	50	M	3½ mo.	x	x	–	x	x	–	–	----	Scattered râles	BM	Edema Hydrothorax	E	

TABLE I—CONT'D

NUMBER	AUTHOR	AGE	SEX	DURATION OF SYMPTOMS	DYSPNEA	COUGH	HEMOPTYSIS	CHEST PAIN	NEUROLOGICAL SYMPTOMS AND SIGNS	CYANOSIS	EDEMA EXTREMITIES	CARDIAC SIGNS	PULMONARY SIGNS	POSTMORTEM FINDINGS			
														THROMBUS SITE OF	PULMONARY	CARDIAC	
11	Billings[8] (1921)	60	M	3 wk.	x	x	x	–	–	–	x	Arrhythmia	Râles	BM	Infarct Edema	E	
12	Rouslacroix[9] (1925)	57	M	2 yr.	x	x	–	–	–	x	x	Fibrillation E	Râles x-ray pulmonary arch prominent	RM	Induration	RVE	
13	Schramm[10] (1927)	44	M	Several mo.	x	–	–	x	x	x	x	Mitral stenosis E	----	RM	Infarcts	RVE	Embolus left iliac artery
14	Barnes and Yater[11]	34	M	1 mo.	x	–	–	x	–	–	–	Failure	X-ray lung abscess	BM	Hydrothorax abscess	RVE Mitral endocarditis	
15	Jump and Bauman[12]	48	M	2½ mo.	x	–	–	–	–	x	x	----	----	BM	Congestion	RVE	
16	Arrigoni[13] (1930)	63	F	2 wk.	x	–	–	x	x	x	–	RVE	----	BM	Edema	Endocarditis Mitral	Thrombus in femoral artery and vein
17	Brenner[14] (1931)	58	F	1 yr.	x	x	–	–	–	x	x	E	Emphysema	RL	Emphysema Edema	RVE	Thrombi in right femoral and left subclavian veins

TABLE I—CONT'D

NUMBER	AUTHOR	AGE	SEX	DURATION OF SYMPTOMS	DYSPNEA	COUGH	HEMOPTYSIS	CHEST PAIN	NEUROLOGICAL SYMPTOMS AND SIGNS	CYANOSIS	EDEMA EXTREMITIES	CARDIAC SIGNS	PULMONARY SIGNS	POSTMORTEM FINDINGS			
														SITE OF THROMBUS	PULMONARY	CARDIAC	
18	Brenner[14] (1931)	49	F	7 mo.	x	x	x	–	–	x	x	E	X-ray shadow lt. lower lung field	LL	Empyema Edema Infarcts	----	
19	Brenner[14] (1931)	60	M	Several mo.	x	x	–	–	–	–	–	----	----	RU LL	Emphysema	----	
20	Boswell and Palmer[15] (1931)	39	M	4 wk.	x	–	–	x	–	x	–	----	X-ray shadow rt. hilus	BM	Infarct	----	
21	Means and Mallory[16] (1931)	60	M	1 yr.	x	–	–	–	–	x	x	E	Edema	RM	Small	E Congenital aortic valve	
22	Desclin and Regnier[17] (1931)	53	M	4 mo.	x	x	–	–	–	x	x	E Syst. and diastolic murmurs	Consolidation rt. base. X-ray cavity rt. base	RM	Abscess Pneumonitis	Syphilitic aortitis, insufficiency	Both iliac veins thrombosed
23	Desclin and Regnier[17] (1931)	55	M	5 wk.	x	x	–	–	–	x	x	----	----	BM	Congestion	----	Rt. femoral and iliac vein thrombosed
24	Kampmeier (1933)	46	F	5 wk.	x	x	–	x	x	x	–	----	Pleural effusion. X-ray shadow rt. hilus	RM	Infarct Fibrosis	Mitral stenosis	Thrombus in inferior vena cava

Cardiac signs and cardiac postmortem findings: E, enlargement; RE, right heart enlargement; RVE, enlargement of right ventricle.
Site of pulmonary artery thrombosis: BM, bilateral main branches; RM, right main branch; RL, right lower lobe branch; LL, left lower lobe branch; RU, right upper lobe branch.

Past and Family Histories. These were negative.

Physical Examination. Only findings of interest are recorded. Proptosis of the right eye and attendant conjunctival edema were noted. The left cardiac border was 10 cm. from midsternal line. On one occasion only, a low-pitched presystolic murmur was heard at the apex. Pulse rate was 72, and blood pressure 120/70. Lungs were clear. The abdomen was negative except for the distended bladder. Pelvic examination revealed a mass the size of an orange considered to be a fibroid uterus.

Neurological Examination. The pupils were unequal and reacted sluggishly to light. There was moderate ptosis of the right upper lid and paresis of the right external rectus muscle. The left arm and leg could be moved to some extent, but there was definite paresis. On the left, the deep reflexes were hyperactive and fanning of the toes occurred on plantar stimulation.

Laboratory Data. Urine was negative. Hemoglobin was 82 per cent (Dare). Red cell count was 5,250,000, white cell count 10,000 with a normal differential picture. Blood Wassermann and Kahn tests were negative. The spinal fluid, five days after the convulsion, was clear, yellow and under 16 mm. of pressure, globulin was increased. Stereoscopic roentgenograms of the skull were negative.

Clinical Course. By the twelfth day the patient had regained complete use of the left arm and normal bladder control. Slight residual paresis persisted in the left lower extremity. Mental symptoms, proptosis, and haziness of the eyegrounds had cleared.

On June 7, six weeks after the convulsion, the patient was seen because of dyspnea which had been increasing for several days. There was slight productive cough but no chest pain. The patient was found sitting upright, obviously cyanotic and very dyspneic. Tachypnea and tachycardia were present. The heart was displaced slightly to the left, and an apical systolic murmur was heard. The right hemithorax was immobile. Signs of pleural effusion were present on the right. A mass was now palpable above the symphysis pubis. A leucocytosis of 15,000 was present, as well as albumin and pus cells in the urine. Temperature was 100° F. Slightly over a liter of straw-colored fluid was aspirated from the right chest. This showed 530 cells per c. mm., of which 84 per cent were lymphocytes.

Aspiration was followed by some relief of dyspnea, and by the demonstration of breath sounds and râles at the right base. However, symptoms again became aggravated. The temperature curve varied from normal to 102° F. Two weeks after the first thoracentesis, 1,500 c.c. of blood-tinged fluid were removed. Many eosinophiles were present in the fluid. Now a friction rub, as well as râles, was present in the lower axilla. It must be emphasized that there was not the slightest improvement in either dyspnea or cyanosis after this aspiration. For the first time the patient complained of pain in the right chest.

Five days later 1,300 c.c. of bloody fluid were aspirated. Stereoscopic chest plates showed, aside from some residual fluid, a triangular shadow at the periphery of the right middle lobe, and a shadow extending downward and laterally from the hilus into the lower portion of the right lower lobe. Dyspnea was marked and the cyanosis was the most intense in my experience, at times the patient appeared almost black. She was forced to sit up constantly. Five days after the last aspiration and about five weeks after the onset of dyspnea she suddenly developed a severe paroxysm of cough and died instantly.

Autopsy. This was done by the author. The brain was fixed in formalin, and on sectioning injection and pigment deposit was found in the gray matter of the upper part of the precentral gyrus.

Upon opening the thorax, the left pleural cavity was found to be negative. The right contained 300 c.c. of bloody fluid. Numerous light adhesions were found over

the whole right lung, except at the base where they were more dense. The abdomen contained some free fluid. An irregular, nodular and cystic mass, 17 cm. in diameter occupied its lower part. This mass which was not adherent, involved the left ovary; the left tube and broad ligament being spread out over it. The right adnexa and uterus were normal. No lymph gland or peritoneal metastases were found. Liver and spleen were negative. On section, the ovarian tumor was found to be a multilocular cyst.

The heart was slightly enlarged, the right side being dilated. Ventricular walls were not hypertrophied. The mitral valve was scarred and presented a moderate degree of stenosis; however, there was no evidence of recent endocarditis. The aorta

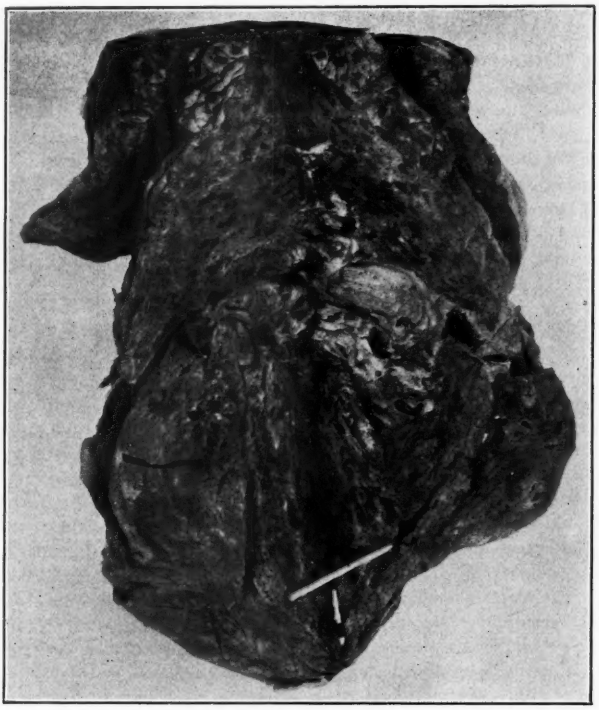

Fig. 1.—Right lung showing thrombus in main branch to the lower lobe, which is collapsed and fibrotic.

and its valves, as well as the valves of the right heart, were negative. The foramen ovale was patent, 1 cm. in diameter, and was covered by a flap of endocardium. Projecting into the right auricle from the inferior vena cava was a canalized thrombus 7 cm. long and 8 mm. in diameter. The auricular end was rounded off. The distal end was squared off as if it had recently broken from some other part.

The left lung was normal. The lower lobe of the right lung was airless, shrunken, firm, and cut with difficulty, appearing to be fibrous. A grayish white firm mass, an organized thrombus, occupied the right main branch of the pulmonary artery and completely occluded all of its branches in the right lower lobe. From the bifurcation of the pulmonary artery to the point of origin of the branch supplying the upper lobes, the lumen was filled to two-thirds of its diameter by the gray thrombus. The

other third and the upper lobe branch were filled by a recent dark antemortem clot. A recent hemorrhagic infarct was present on the axillary surface of the middle lobe at its lower border. The lung was cut in thin sections, but no gross evidence of metastatic nodules could be found. (Fig. 1.)

Microscopic findings were reported as follows: "Old infarcted area in the cerebral cortex; pseudomucinous adenocarcinoma of the ovary; organized thrombus of the pulmonary artery and recent infarct of the middle lobe of the right lung; fibroblasts and other signs of organization present in pulmonary artery thrombus as well as in that found in the inferior vena cava."

COMMENT

The varied clinical manifestations and the number of pathologic findings in the case are of interest, though their interrelationship is still not clear. Abdominal pain appeared first, to be followed by central nervous system symptoms. The murmur of mitral stenosis was heard. An enlarging pelvic tumor then presented itself. Later appeared dyspnea and marked cyanosis, associated with serosanguineous pleural effusion, to be followed by sudden death. At first the diagnosis was clouded, but it soon appeared that we were dealing with neoplasm in the pelvic organs which had metastasized to the lungs, and that embolism had occurred from there to the brain.

The pathologic findings were of great interest. The ovarian tumor was of the type in which metastasis is rare, and it is certain that none took place to the lung. The mitral lesion was old and moderate and thus could not account for cerebral embolism. A canalized, organized thrombus projected into the right auricle from the inferior vena cava. Possibly this had formed in an iliac or femoral vein, judging from its caliber. Sudden death may have been due to the breaking loose of this thrombus; this is merely a matter of speculation. In any case it may well have been the source of small thrombotic emboli which occluded some of the smaller branches of the right pulmonary artery and thus led to gradual extension thrombosis. We know that occlusion was a slow process because five weeks elapsed from the onset of pulmonary symptoms to the time of death. The infarct of the middle lobe was probably associated with more recent embolism and thrombosis of the branch supplying the upper lobes. Still the source of embolism to the brain is not explained. It may have been due to thrombosis on the venous side of the lesser circulation, associated with the early embolism to branches of the pulmonary artery. The patent foramen ovale was too satisfactorily closed to be seriously considered in relation to cerebral embolism.

ETIOLOGY OF PULMONARY THROMBOSIS

Among the etiologic considerations, two seem to be of major importance. These are atheroma of the pulmonary arteries and embolism.

Atheroma of the pulmonary arteries followed by thrombosis was found to be present in eleven of the twenty-four collected cases. In his monograph on diseases of the pulmonary artery, Posselt[2] states his belief that thrombosis is the result of atherosclerotic changes of the intima; though he does admit that at times it may appear to be primary. Atheroma of the pulmonary arteries is considered by some to be syphilitic in origin, especially so in the clinical syndrome known as Ayerza's disease. Brenner,[14] however, believes that though sclerosis may be primary or syphilitic, it is more frequently secondary to fibrosis or emphysema of the lung, or to mitral stenosis.

Embolism is the other etiologic factor in the production of thrombosis. There was proved thrombosis in the venous system in five, or in 20.8 per cent, of the collected cases, this being found in the femoral or iliac veins in four of the cases and probably occupying the same site in the fifth. Search would probably have disclosed similar thrombi in some of the other cases. Though Means and Mallory[16] could find no source of emboli in their case, they nevertheless felt that the pulmonary thrombus was accounted for on that basis. It is believed by several authors that embolism occurs in a branch too small to give the characteristic symptoms of pulmonary embolism with infarction. The small embolus then by accretion develops into a progressing thrombosis gradually extending and involving the main branches of the pulmonary artery. Arrigoni[13] in the discussion of his case points to successive attacks of chest pain as indicating embolism at different times.

Holman and Mathes,[18] in a study of intrapulmonary suppuration associated with embolism, found that when one sterile and one infected embolus were injected almost all the animals developed hemorrhagic infarct, and some abscess. From this viewpoint it is of interest to find that two cases of lung abscess occurred in the twenty-four collected cases of pulmonary artery thrombosis.

Pressure upon a branch of the pulmonary artery with consequent slowing of the blood stream and resulting thrombus formation may warrant theoretical consideration. In the comments on his case, Schramm[10] calls attention to the high grade mitral stenosis with attendant dilation of the left auricle containing masses of thrombi. The auricle lies in proximity to the right main branch of the pulmonary artery, probably pressing upon it and so causing slowing of the stream, conducive to thrombosis. He felt that this finding or embolism was the cause in his case.

In this group of collected cases, seven or 29 per cent were females. The age limits in the group were from twenty-six to sixty-five years. The average age was forty-four years. Three cases each occurred in the third and fourth decades. The remaining eighteen cases were almost equally distributed in the fifth, sixth, and seventh decades.

PATHOLOGY

Thrombosis of the main branches of the pulmonary artery was found to be bilateral in eleven or 45 per cent of this series of collected cases. In ten others the right side only was involved, whereas in only three the left pulmonary circulation was involved alone. As noted above, atheroma of the pulmonary arteries was found in eleven or 46 per cent of the cases.

The data in some cases are not complete as to certain details. However, in seven cases, or in 29 per cent, the right heart was shown to be hypertrophied or dilated, or both. In seven others the heart was merely described as being enlarged. Two cases presented mitral stenosis, and two more were described as showing endocarditis of the mitral valve. One case had a congenital anomaly of the aortic valve with stenosis, and one syphilitic disease of the aortic valve.

Pathologic findings in the lungs were varied and were not at all constant. Eight cases, or 33 per cent, showed hemorrhagic infarction. In two cases was found solitary pulmonary abscess. Edema of the lung was noted seven times, and in two merely engorgement. Emphysema was described three times.

Thrombosis in femoral or iliac vein occurred in five cases.

SYMPTOMS AND SIGNS

The duration of symptoms was recorded in all but two cases. This varied from two weeks, the shortest, to three years, the longest. In five the symptoms persisted over one year, while in fifteen the course was run in less than seven months.

Symptoms were mentioned in all but one of the cases. (Table I.) Among the complaints we find dyspnea and cough to be the most frequent. Dyspnea was noted in twenty-two, or in 91 per cent. Cough appeared in twelve, or 50 per cent. Hemoptysis occurred in five patients. Chest pain was recorded in seven. Neurologic symptoms and signs are of interest and appeared too often in such a small series of cases to be more than coincidental. Hemiplegia, aphasia, and paresis of the facial muscles were found, one or more of these occurring in seven patients, or in 29 per cent of the cases.

Of signs, the outstanding seems to be cyanosis, of such degree that several authors have dwelt upon the intensity of its appearance. It is reported in all but six cases. Cardiac enlargement was described in eleven, or 46 per cent, of the cases, its enlargement to the right being noted in three cases. Mitral stenosis was diagnosed in three; in my case the murmur was heard on one occasion but could never be verified. Auricular fibrillation occurred once, and a systolic and diastolic aortic murmur were heard in one case. In twelve, edema of the lower extremities was found.

Abnormal physical findings in the lungs are remarkable by their rarity. Emphysema was described in three cases. Dullness on percussion was noted three times, râles were heard in four, and bloody pleural fluid was found in two cases. Roentgenologic examination was used in only five cases. Lung abscess was recognized in two of these. Shadow in the right hilus was noted in two cases, and radiopacity of the lower lobe in the fifth case.

DIAGNOSIS

The object of the collection of this group of cases has been to learn whether a clear-cut syndrome can be evolved enabling one to entertain a diagnosis of thrombosis of a main branch of the pulmonary artery. In no reported case was the diagnosis made.

It seems that the diagnosis of thrombosis of a large branch of the pulmonary artery may be considered under the following circumstances. There will be progressing dyspnea, going on to orthopnea. Cough may or may not appear; hemoptysis and chest pain occur in occasional cases. The outstanding finding from the onset is cyanosis, becoming more intensified with the progress of the condition. After a varying interval, possibly hypertrophy, more certainly dilatation, of the right heart will occur with appearance of edema of the lower extremities in a fair proportion of cases. Abnormal findings in the lungs are uncommon and may consist of dullness, râles, and occasionally pleural effusion. The unexpected paucity of pulmonary signs should be emphasized. The roentgen ray examination if utilized more in the future may show hilus shadows which are suggestive in aiding in the diagnosis.

The diagnosis of chronic pumonary thrombosis is not an abstract consideration, since the patient may live weeks or years suffering with this clinical picture. Therefore the diagnosis is desirable aside from its purely academic interest.

In the differential diagnosis must be considered those conditions which are characteristically associated with cyanosis. Congenital heart disease by nature of its clinical picture and the age of the patient need not be considered. Mediastinal disease is characterized by cyanosis of the parts above the level of the obstruction to the venous return and the development of a collateral circulation. Ayerza's or Osler's disease presents splenomegaly, polycythemia, and increase in hemoglobin. Mitral stenosis is probably the most common condition in which the picture of pulmonary thrombosis might be confused. (As seen in this series both these conditions may be present at the same time.) However, the absence of the typical murmur and the lack of findings of congestion of the lungs which one would expect in right heart failure would be significant. The roentgen plate would be of assistance if a shadow of a thrombus were found in the hilus. Lastly, 75 per cent of this series of collected cases of

pulmonary thrombosis fall into the fifth, sixth and seventh decades when failure due to mitral disease is more uncommon. Pulmonary fibrosis may lead to dyspnea and cyanosis with eventually right heart failure. The characteristic history of productive cough and the roentgenologic findings should clearly make the diagnosis. In the presence of long-standing marked pulmonary emphysema we again find dyspnea, cyanosis, and right heart failure, but there is frequently a compensating polycythemia. Furthermore, in the presence of such degree of emphysema pulmonary thrombosis would probably not be considered. In the twenty-four cases, emphysema of the lung was mentioned in the pathologic notes only three times, indicating that this question would rarely arise.

SUMMARY

1. Twenty-three cases of thrombosis of the main branches of the pulmonary artery have been collected from the literature. Another has been added.

2. Diagnosis of the condition is desirable because these patients may live from weeks to years before death intervenes.

3. From this study a syndrome may be described. This consists of progressively increasing dyspnea, with or without cough. Chest pain may be present in some cases. The outstanding sign from the onset is cyanosis becoming intensified as the condition progresses. Right heart failure may occur. Pulmonary signs are uncommon.

(NOTE: The reported case was referred by Dr. J. W. White of the Pueblo Clinic, and was studied at Parkview Hospital, Pueblo, Colo. Laboratory studies were conducted by Dr. C. W. Maynard.)

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A RETRACTOR FOR ELEVATION OF THE SCAPULA DURING THORACOPLASTIC OPERATIONS

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IN PRESENTING a retractor for elevation of the scapula during thoracoplastic operations, we have in mind the difficulties that are encountered with the use of retractors that are devised for abdominal operations. The retractors that are here presented have been selected after several months of constant use, with many modifications having been made. They have been used, however, for several months as they are now presented. It will be noted that the handle of the retractor has been made comparatively short and that it joins the blade of the

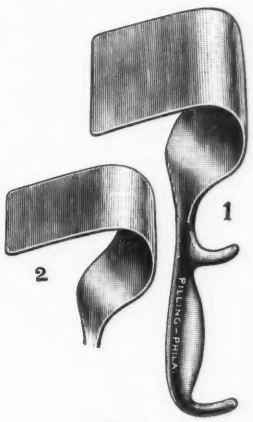

Fig. 1.

retractor very close to the surface of the structures to be lifted. This is of distinct advantage, as it brings the hand of the one who is holding the retractor very close to the structures which he is attempting to elevate from the operative field and gives him better control of these structures. Another feature that we feel is of distinct importance is the fact that the center of the lifting power is transmitted to the broad surface of the retractor just proximal to its central point, rather than to either end of the blade. This eliminates the aggravating tendency for the retractor to slip out of the wound, in fact, the retractor tends to slip further under the scapula when pulled upon. Another feature which we have found of distinct advantage is the broad lifting surface.

We have used two different widths, as indicated in the photographs: the broader retractor (1) is used in large individuals, and the narrower one (2) is used in smaller individuals. Another point of interest is the elimination of all sharp angles as related to the blades of the retractor. This permits the structures to fit into the curves of the retractor and eliminates the projection of the retractor into the operative field.

TRANSACTIONS OF THE NEW YORK SOCIETY FOR THORACIC SURGERY

PRESIDENT, DR. CARL EGGERS; SECRETARY, DR. HERBERT WILLY MEYER

MEETING OF NOVEMBER 24, 1933

Incision and Drainage for Suppurative Basal Tuberculosis. CARL EGGERS, M.D.

The patient is a married woman, forty-four years of age. There are several interesting points connected with her history and treatment:

1. The comparative infrequency of isolated basal tuberculosis.

2. The association of the lesion with an acute empyema of Type III pneumococcus.

3. The fact that the lesion did not manifest itself until after drainage of this empyema.

4. That no diagnosis was made until after operation for the suppurative process in the lung.

5. That there has been remarkable improvement in the patient's condition since establishment of drainage.

The patient was first seen in consultation January 12, 1933, on account of a suspected empyema. She had contracted influenza two weeks previously which was complicated by a left lower lobe pneumonia. The sputum showed pneumococcus Type III. The temperature had remained at 104° F. for five days and had since then gradually come down, reaching 99° for the first time that morning. Slight cough had persisted, there were no other symptoms except weakness. The patient looked quite well and had good color. She had herpes of the lips, and rather rapid respiration. On examination there was dullness at the left base, most marked in the axilla, but fremitus was present and some fine crepitant râles were heard over the area of dullness. There was no displacement of the heart. Bedside x-ray plates had been taken but were unsatisfactory. The condition impressed as a resolving pneumonia, rather than empyema, and exploratory puncture was not advised.

She was seen again a week later on account of persistence of symptoms, especially dry cough and fever running up to 103.5° during the last few days.

Physical signs were misleading. There was dullness over the left base but fremitus was present, and breath sounds and crepitant râles could be heard. The most marked dullness was in the left axilla, and there seemed to be distant bronchial breathing, but even here some râles were heard. Nevertheless there was a suspicion of fluid, and an exploratory puncture was done about the middle of the lower part of the axilla. The first puncture was negative, but the second one, in the space below, apparently the sixth, resulted in the withdrawal of thick pus, which later showed pneumococcus Type III.

Operation was performed the following day, January 20, 1933, under local ½ per cent novocaine anesthesia. About 9 cm. of the sixth rib were resected in the midaxilla. The empyema cavity was entered and a large amount of thick pus evacuated by means of suction. The opening was enlarged and fibrin masses were removed. Exploration then showed that the cavity had been entered at its extreme posterior margin and that it was bounded posteriorly by lung. Anteriorly it extended downward and forward for at least 15 to 20 cm. In order to get good

drainage it was necessary to resect an additional 9 to 10 cm. of the sixth rib. The cavity was then well exposed; it rested on the diaphragm and extended downward and forward to the extreme anterior margin of the costophrenic sinus. After completely cleaning the cavity, pus continued to flow from a small opening far forward, apparently situated between the diaphragm and the base of the lung anteriorly. This opening was enlarged, and considerable pus and fibrin were evacuated. Two large drainage tubes were inserted, resting on the diaphragm, and the posterior and upper part of the wound was then closed.

Instead of the temperature dropping to normal, as had been anticipated, it remained at about 103° for five days and then rose to 105°. Then followed weeks of high fever ranging from 99° F. to 106° F. in the course of a few hours. With it all the patient did not feel particularly sick. She complained of feeling hot and had a hacking cough, usually unproductive. Careful examinations failed to reveal the cause of the temperature. There was apparently no pocketing of pus, no new focus of pneumonia, no pericarditis, no phlebitis, and no pyelitis. Carrel-Dakin treatment was instituted to sterilize the cavity and minimize absorption, and a transfusion and several x-ray treatments were given, all without apparent effect. A blood culture was done twice, each time negative. Tuberculosis of the underlying lung was considered, especially in view of a tuberculous family history, but repeated sputum examinations were negative, and x-ray examinations of the lungs showed no characteristic lesions. It had been noted that the patient had a husky voice ever since she was first seen. Examination of the larynx showed complete paralysis of the left vocal cord in the position of adduction. There was no evidence of tuberculous laryngitis.

Several exploratory punctures about the region of the tip of the scapula were negative for pus. The needle seemed to enter solid lung and on one occasion pure blood was obtained.

A final résumé of the case almost four weeks after her empyema operation showed the general condition of the patient unchanged. She had no special complaint, there was no pain anywhere. The empyema wound looked clean and showed great tendency to heal. The temperature continued high, sometimes ranging from 97° to 106° F. in the course of a few hours. The voice continued husky because of left vocal cord paralysis. No complications had been made out. Blood culture and sputum were negative.

On physical examination the heart was found drawn over into the affected thorax; the heart sounds were of good quality. There was no evidence of peri carditis. Over the left lower lobe dullness was found posteriorly and in the axilla associated with bronchial breathing and crepitant râles. At times there was a little hacking cough without expectoration.

This combination of physical signs and symptoms, with the mediastinum drawn over into the affected side, and with repeatedly negative pleural punctures, made us feel that we were dealing with an intrapulmonary suppurative lesion. The exact nature of this lesion was doubtful. We considered an extensive infarct with secondary infection, abscess formation in the interstitial tissue or possibly a bronchial tumor with secondary bronchiectasis. A bronchoscopy was suggested but in view of the patient's condition it was deferred.

Operation in the nature of an exploration was decided on, to establish drainage in case a suppurative focus were found.

It was performed February 21, 1933, a month after the empyema operation, under light avertin anesthesia. About 20 cm. of the seventh rib were resected. The rib bed looked and felt thickened. It was incised for its entire length. The tissue was edematous, and there was agglutination of all the layers, so that the

pleural cavity could not be identified. The incision was carried directly into the lung tissue for a depth of from 2.5 to 3 cm. It was firm in parts, while in other parts it had broken down and formed small abscesses. With a blunt clamp, punctures were made into the lung in different directions, and the process was then repeated with a cautery. There was no escape of air and no serious bleeding was encountered. The entire suppurative lesion seemed to be extrabronchial. An attempt was made to separate the pleural layers for extrapleural exploration but that was not possible. Cultures and smears were made, and a piece of lung was excised for examination. No extensive cauterization was carried out on account of the danger of severe hemorrhage. An iodoform gauze tampon was packed into the incised lung, vaseline strips were inserted down to the lung to surround the iodoform tampon and to protect the muscle layers and skin against infection. The wound was left wide open. The operation was well borne. A transfusion of 500 c.c. whole blood was given.

Culture of the pus from the lung was negative.

The original smear showed broken down and partly disintegrated pus cells and no microorganisms.

The section of lung tissue showed chronic tuberculosis with typical tubercles.

For some time after operation it appeared that the procedure had no appreciable effect on the course of the disease. The patient had no special complaint except the added discomfort of the wound and perhaps more cough than formerly. The temperature showed a daily rise to 105° F. for about two weeks, and then it gradually came down. For about a week it would reach 104° F. at night, then 103° F., and so on down until the latter part of June the highest evening rises would be about 100° F. Coincident with this decline of temperature there appeared several bronchial openings in the exposed lung after the slough produced by the cautery had been cast off. Considerable mucopurulent secretion was discharged from these bronchi, and the cough became less. There was gradual improvement in the patient's general condition and she began to gain weight, aided by all the hygienic and dietary measures used to combat tuberculosis. In an attempt to verify the diagnosis of tuberculosis the sputum and the bronchial secretion were repeatedly examined for bacilli, but always with a negative result. Bronchial secretion was then injected into a guinea pig and typical tuberculous lesions were found two months later. Since then the bacilli have also been recovered from the sputum.

The patient was discharged from the hospital with a bronchial fistula on June 30, 1933. She has continued to improve and has gained thirty pounds in weight. A recent roentgen ray examination shows a lesion suggesting bronchiectasis in the left lower lobe. The other lobes are uninvolved.

No attempt has been made to keep the bronchial fistula open; it has shown no tendency to heal. The question now is, should one leave it as a safety valve in the hope that the extensive intrapulmonary focus may clear itself in this way, or would it be better to close it? What is the prognosis in such a case? At present there is not sufficient information available to answer that question.

About the frequency of isolated basal tuberculosis, opinions vary a great deal. Some authors state that it is very uncommon, that it is frequently associated with tuberculous lesions in other parts of the body and that the mortality is very high. We have not been able to find involvement of any of the patient's other organs. The larynx does not show tuberculosis. The paralysis of one vocal cord is probably due to disease in the mediastinal lymph nodes. That the drainage operation in this case probably influenced the prognosis, there seems to be no doubt. Surgical drainage of tuberculous cavities, either intentionally or accidentally produced, is known to have led to great improvement. One may speculate on other surgical

possibilities in this case. Should improvement continue, and a bronchial fistula persist, with an underlying bronchiectatic lobe, would it be justifiable to attempt lobectomy? For the present we shall continue a conservative course.

Tumor Right Lower Lobe—Lobectomy—Cure.* ETHAN FLAGG BUTLER, M.D.

The patient was a white woman, single, twenty-three years of age, a clerk in a store in a small town of northern Pennsylvania. She was referred for examination on February 16, 1933, by her family physician, on account of cough, and loss of weight, strength and appetite. In childhood she had had measles, mumps, whooping cough, chickenpox, scarlet fever and diphtheria. She had also had three attacks of "pneumonia" between the age of one year and fourteen years. Each of these attacks had been long and severe, but further details could not be obtained.

The present illness began about December 1, 1932, with pain in right side of back and shoulder which radiated into front of right chest and abdomen and, to a less extent, into left chest. There had been fever, headache and nausea for a few days at onset. This subsided but was followed by a persistent paroxysmal cough with copious, purulent sputum. There was no history of hemoptysis. Within the last month there had been some afternoon temperature.

Physical examination showed a fairly well-nourished girl. Blood pressure was 122/76. Tonsils were enlarged. There was no evidence of pyorrhea or dental infection. Nose and sinuses were free of disease. The breath was fetid. The right side of the chest was retracted, and the respiratory excursion was definitely limited. Vocal fremitus was absent at the right posterior base; elsewhere it was better transmitted on the right than on the left. The percussion note was resonant throughout. Occasional râles could be heard on the right, otherwise the breath sounds were vesicular and normal. Physical examination of the heart was quite negative. The abdomen was slightly tympanitic with slight tenderness along the right costal margin. In all other respects physical examination was negative.

Roentgenologic examination included fluoroscopy of chest and supraglottic lipiodol pneumonography. Fluoroscopy showed a decreased excursion of the right side of the diaphragm. The heart was normal. The lung fields were negative until the patient was rotated into the oblique position, when there was brought into view a sharply circumscribed, dense shadow about 5 cm. in diameter located in the lower right paravertebral corner. This shadow did not move with respiration; it was almost hidden at expiration by the shadow of the diaphragm, but was clearly visible at full inspiration. Following supraglottic administration of lipiodol, there was no evidence whatever of bronchiectasis, but the oil did not enter the area of the dense shadow.

The sputum showed no tuberculosis bacilli, rare Vincent organisms, few streptococci, and few pus cells.

Urine and blood count were essentially normal.

The diagnosis lay between chronic suppuration and tumor of the right lower lobe. Exploration was advised, and was accepted by the patient.

On February 21, 1933, under nitrous oxide anesthesia, the first stage was carried out. The technic of John Alexander was followed closely, except that the flap was hinged posteriorly instead of superiorly. After the chest was opened, it was possible to see and feel a mass occupying the posterior lower corner of the lower lobe. The lobe was adherent by broad bands in the spinal gutter. The remaining portion of the lower lobe and the upper and middle lobes appeared normal. The entire pleural surface was wiped with dry gauze to promote defensive

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adhesions and the operative wound tightly closed. An air-tight tube for pleural drainage was introduced through a separate stab wound. There was no shock or other untoward occurrence.

On February 27, 1933, under local procaine anesthesia, a right temporary phrenic block was performed. The pleural drainage tube had been removed at the end of three days. The residual postoperative pneumothorax had completely disappeared. A few days later the patient was allowed out of bed.

On March 6, 1933, under nitrous oxide anesthesia, the second stage was undertaken, but was not completed because of air suction between the upper lobe and the mediastinal pleura. The wound was promptly closed without drainage. However, an apical pneumothorax resulted which caused embarrassment and gave an intrapleural pressure reading of +8 +6. There was shifting of mediastinum to the opposite side. Deflation with removal of 400 c.c. of air afforded relief and gave a final pressure of −4 −6. A transfusion was also given.

On March 18, 1933, under nitrous oxide anesthesia, the third stage was undertaken. This time the lobe was safely resected, the pedicle satisfactorily secured with mass ligatures, and the wound left wide open, there being no further leakage of air. A second transfusion followed.

From that time on, surgical convalescence was satisfactory. The wound remained relatively clean. There was no postoperative hemorrhage. The maximum temperature was 102° F. A third transfusion was given on March 23, 1933. All pedicle slough had separated by April 11, 1933. The patient was discharged from the hospital on April 16, 1933, to a convalescent home where satisfactory dressing care could be secured, and where her general condition showed rapid improvement. On May 12, 1933, she returned to her home, 45 miles from Elmira, but still reported back for simple dressings at two- or three-day intervals, until the final healing of the wound during the latter part of August, 1933. By that time she had gained more than 25 pounds in weight and had been able to return to work.

On Nov. 10, 1933, the patient reported for follow-up examination and was found to be in thoroughly satisfactory condition. There was no evidence of any recurrence of the original pathologic condition.

The pathologic examination of the tissue resulted in conflicting reports, which varied from teratoma to organized healed abscess. The tissue was finally submitted to the Chest Tumor Registry and the final decision of Dr. N. C. Foot was:

Gross Material: A lobe of lung that has been converted into an almost solid mass of porklike, brawny connective tissue in which little structure resembling that of healthy lung can be found.

"Microscopic Examination: The lung tissue has been divided up into districts by dense bands of fibrous tissue probably representing interlobular septa. These run through the section from a somewhat denser, outer mass of hyalinized connective tissue, separating it into circular areas that are seen to contain bronchioles, much lymphoid tissue, occasional cartilaginous structures like rings of bronchi, circular alveoli lined with cuboidal epithelium and, finally, much granulomatous tissue.

"The bronchioles dominate the picture in the higher-powered microscopic fields. They have apparently multiplied to an enormous extent, but this may be due to consolidation of considerable areas of tissue into small compass and consequent bringing together of many bronchioles that normally covered a good deal of area into a small district. They are lined by many-layered, columnar, ciliated epithelium and show no evidence of anaplasia or metaplasia, although they are hyperplastic. Some of the smaller bronchi show dilatation and a filling of their lumina by plugs of mucopus; sometimes this is loaded with anastomosing phagocytic cells that give

it an appearance of having been partially organized. There is some evidence of alveolar pulmonary tissue between the branching bronchioles and this is lined with embryonal, plump cuboidal epithelium, such as one sees in the embryonal lung, or in areas of pulmonary tissue in advanced chronic phthisis. The lymphoid tissue is also hyperplastic. The granulomatous areas show the usual components; lymphocytes, plasma cells and macrophages, with fibroblasts and a great many polymorphonuclear leucocytes. The fibrous tissue is quite inert and hyalinized, with the appearance of cicatricial tissue.

"It would seem that a considerable area of lung had been shut off from air circulation by an inflammatory process, that the bronchioles had become plugged, and that as a consequence the pulmonary tissue had undergone quasi embryonal changes and the bronchi (possibly) attempted to regenerate pulmonary tissue. The entire process could, I think, be explained on a purely inflammatory basis. The heterogeneity of the picture suggests teratoma, it is true, but only for a moment; there is too much real differentiation into lung elements for this to be a tumor.

"Diagnosis: Atelectasis fibrosis and possible bronchiolar proliferation as a sequela to past inflammation, possibly abscess."

Cardiospasm of the Esophagus. JOHN V. BOHRER, M.D.

M. H., a nineteen months' old infant girl, was admitted to the Children's Surgical Service, Bellevue Hospital, April 29, 1933. Her mother gave a history that the baby had a normal delivery at full term and was apparently normal in every respect. She is the ninth child in the family. One died in infancy of convulsions; the others are all healthy. She was breast fed and took her feedings normally for the first week. From that time on she would nurse a short length of time and then immediately regurgitate. This regurgitation seemed to be undigested milk, and laboratory findings proved that it had not entered the stomach. For intervals of two or three weeks the baby would be relieved of this regurgitation, take her food normally, and then regurgitation would spontaneously recur. The patient remained in fair nutrition, but as the condition had become more exaggerated, she was brought to the hospital for observation. There was no history of swallowing a foreign body or caustics of any kind and no history of salivation or polyuria. While under observation in the wards at Bellevue, it was noted that she could take one ounce of milk without regurgitation and that she could be fed this amount at two-hour intervals, but if two ounces were given at any one time, vomiting followed.

She was given a barium mixture, and x-ray examination was made which showed the upper esophagus markedly dilated with an obstruction about one inch from the cardia. The obstruction was smooth and showed no evidence of ulceration by x-ray. A small quantity of the mixture had passed into the stomach, and there was a hair line connecting the mass retained in the esophagus to that in the stomach. Physical and laboratory examinations of the patient were otherwise entirely normal. From clinical observations and x-ray findings a diagnosis of cardiospasm was made, and the question of treatment arose. Tincture of belladonna was given in physiologic doses with no apparent result. Some of the food taken ultimately found its way into the stomach making it unnecessary to do an emergency gastrostomy. Dilatation of the stenosed area was considered to be the proper treatment. She was, therefore, sent to the Bronchoscopic Clinic where she was seen by Dr. Charles Imperatori who passed an esophagoscope and encountered an obstruction at 20 cm. from the upper teeth. At the point of obstruction marked ulceration was observed, and under observation the stenosed lumen was identified and a No. 10 Jackson's bougie was easily passed into the stomach. Following this a No. 12 bougie readily passed into

the stomach. There was no bleeding. Great care was exercised, however, in passing these bougies as it was apparent that a rupture of the esophagus, especially since it was ulcerated, might readily occur during dilatation.

The result of this treatment was quite phenomenal. The child not only was able to take fluid diet but at once was able to swallow gruel and eat bread, although the cardia had not been dilated to its full size. This treatment was repeated weekly for four weeks and dilated to No. 18 bougie. The child gained weight and was up and about the ward. An epidemic of chickenpox developed in the ward,

Fig. 1.—A-P view showing the marked dilatation of the upper esophagus with the obstruction 22 cm. below the tooth line. A hair line connects the mass in the esophagus and the stomach.

and she was sent to Willard Parker Hospital on account of this contagious disease. During her sojourn in Willard Parker, she remained well and was discharged from that institution in good condition. Eight weeks from her original discharge from Bellevue Hospital she was readmitted complaining of the same symptom complex. An x-ray examination was at once made and demonstrated that the same condition existed. She was referred to the Bronchoscopic Clinic where the esophagus was again dilated under direct vision through the esophagoscope and again the condition responded to treatment. She received six weekly dilatations and was discharged from the hospital with instructions to return to the clinic for monthly observa-

tion. In all, she has received thirteen treatments. Up to the present time, there has been no recurrence, the patient has remained in excellent health, and apparently is cured of her stenosis. X-ray examination made November 3 showed neither dilatation of the upper esophagus nor stenosis of the cardia.

In reviewing the literature on cardiospasm, it is found most frequently in adults, comparatively infrequently in children, and rarely in infants.[1] Simpson reports the youngest on record, an infant two days old. His case was diagnosed, treated and cured. It was necessary to do an emergency gastrostomy, and ten days later he did a retrograde dilatation of the esophagus. Esophagoscopic examination was not done, so the presence or absence of a fissure or ulcer of the cardia was not determined. Suffice it to say that whatever the pathology, the condition was cured by his excellent plan and work.

Much has been written on the etiology of cardiospasm and practically all agree that there is some abnormality of the vegetative nervous mechanism. This at once suggests several questions:

1. If it is a mere physiologic dysfunction, why should simple dilatation cure these cases?

2. Is it a permanent cure or do they recur in adult life and make up at least a part of the numerous adult cases?

3. Is it possible that the condition is not so rare in infancy and, in difficult feeding cases, the esophagus is overlooked as an entity?

4. Is it conceivable that there is always a fissure or ulcer as the real cause of spasm and that dilatation cures this condition and incidentally stops the cardiospasm? Ulceration was present in the above reported case, and was suspected in the case reported by Messeloff, Shulman and Buckstein.[2] Ulcer of the stomach has frequently been observed in infants suffering from pylorospasm and in pyloric stenosis. The answer to these questions can only be had by future observations and study.

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Tuberculoma of the Costal Cartilage. JOHN V. BOHRER, M.D.

H. R., a four-year-old boy, was admitted to the Children's Surgical Service, Bellevue Hospital, February 23, 1933. For five months previous to admission his mother had noticed a small movable lump on his anterior chest wall near the sternum at the level of the fourth rib. This lump neither was painful nor did it show signs of inflammation. The boy was taken to a clinic where apparently no diagnosis was made, but instructions were given him to return at regular intervals so that the lump might be watched. He was eventually referred to a board of health station where a Mantoux test was done. This proved to be strongly positive. It was still positive at date of admission to the hospital, and the size of the tumor was slowly progressing.

Just previous to admission he visited the clinic of Dr. Frank Adair at the General Memorial Hospital where an aspiration biopsy was made. This biopsy revealed typical tubercular tissue. There was no family history of tuberculosis, and no history of cough, night sweats, or loss of weight. He has always lived in and about New York and has always taken pasteurized milk. At the time of admission to the hospital his general physical condition was excellent. He was normal in size, height and weight.

Physical Examination: Lymphatic tissue was not enlarged. The lungs were normal on physical as well as x-ray examination. The gastrointestinal and genitourinary history was normal as was the physical examination.

Surgical Condition: There was a tumor two inches in diameter just lateral to the sternum at the level of the fourth rib. This tumor was moderately firm, semifluctuant, and was fixed to the underlying bony structures. There was no tenderness or signs of inflammation. A diagnosis of tuberculoma involving the fourth costal cartilage was made, and excision was decided upon.

Operation: Consisted of making an elliptical incision about the mass and a complete excision of the tumor. The underlying costal cartilage was roughened and at one spot completely divided (a pathologic fracture). It was completely excised with the tumor mass, removing a small portion of the rib and on the opposite end, a small portion of the sternum. The pleura was very thin and very adherent to the costal cartilage and sternum, but was not involved. A pedicle of pectoralis major muscle was fashioned to fill the space made by resection of the costal cartilage, and the skin, with its layer of panniculus adiposus, was closed over this without drainage.

Pathologic Report: The specimen consists of a piece of rib and costal cartilage 5 cm. in length and 1 cm. in width. The surface is roughened and in one place shows a complete erosion of the cartilage. The remainder of the specimen consists of an irregular piece of fibrous and fatty areolar tissue 6 cm. by 4 cm. On section, parts of the tissue are firm and show a smooth whitish, brown surface. Cheesy, necrotic areas are scattered through the entire tissue.

Microscopic Examination: Reveals tubercular granulation tissue showing typical tubercles.

The convalescence for the first five days was uneventful. The skin sutures were removed and the wound had healed per primam. On the tenth day, however, the temperature became elevated, and I feared a deep infection of the wound. Wound inspection revealed no trouble, but a diagnosis of measles was made. The patient was then sent to the Willard Parker Hospital for his infectious disease, from which institution he was discharged home with wound healed.

During the following month the skin edges of the wound separated slightly and a superficial sinus was observed. The slight discharge was entirely serous. I feared we were dealing with a recurrent infection in the cartilage and thought it might involve all the costal cartilage of the right side of the sternum (this often being the case in nontubercular infections involving a costal cartilage). Conservative treatment was decided upon, and he was treated daily by heliotherapy. The entire chest was exposed to direct sunlight. This was done progressively in order to avoid a sunburn, and a good skin tan was soon established. Alpine light was also given twice a week. A diet rich in calories and vitamins was prescribed and taken. This resulted in a gradual improvement, but the soft tissue sinus was slow in healing. As an experiment, a dressing saturated with staphlo-lysate (Lilly) was applied, and two days later 2 c.c. of the lysate were injected with a hypodermic into the tissue about the sinus. There was a moderate inflammatory reaction for two days, and on the sixth day the sinus had closed and has remained so. I mention the lysate simply because I used it and the sinus closed. No conclusions can be drawn from one case; however, I am using it on a second case with satisfactory progress.

This case is presented for several points of interest:

1. The costal cartilage is not commonly involved in a tubercular lesion, especially a primary lesion.

2. Resection of the cartilage cured the cartilaginous lesion.

3. The soft parts retained the infection, developed a sinus, but eventually healed by heliotherapy, and application of staphlo-lysate (Lilly).

Intrathoracic Foreign Body With Chronic Empyema Suggestion to Aid X-Ray Diagnosis. HOWARD LILIENTHAL, M.D., F.A.C.S.

This patient, a man of fifty-five years, was referred to me in May, 1933, for the treatment of a chronic empyema with chest wall fistula. He had been operated upon more than eight years before for an empyema of the right chest which appeared to be successful, for he remained well until March, 1932, when he was operated upon for recurrence of the empyema which had been initiated with cough and expectoration of a fair amount of nonodorous mucopus. Drainage with resection of rib had been performed at this time, but the wound failed to close, and there were several subsequent operations. The fistula remained open.

When I first saw him, I found a cicatrix in the lower right chest with a discharging sinus. X-ray examination suggested the presence of pulmonary suppuration low in the chest but there was no fetor. The discharge was sufficient to require daily dressings, and on examination I found a collection of undrained pus.

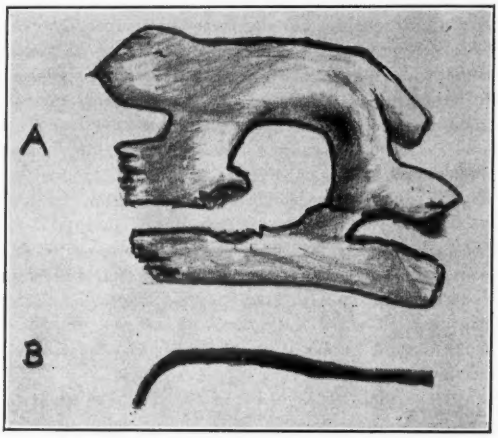

Fig. 1.—*A*, Specimen of bone; *B*, the foreign body.

After such a long history with so many operations it appeared to me that this patient should have the benefit of a complete surgical exploration and I sent him to the semiprivate pavilion at Mount Sinai Hospital, which he entered on May 19, 1933. Here, after the usual observations, including blood grouping, I injected iodized oil into the sinus and with the aid of the x-ray a number of tracts were seen with two pools, each of which seemed to hold about an ounce. The tracts were tortuous and complicated but were all in the lower right chest.

Two days later I operated. The man was anesthetized by Dr. Branower, who administered avertin, then nitrous oxide and oxygen.

The first step was to inject a solution of methylene blue into the sinus. Then a long incision was made in the eighth interspace surrounding the sinus and continued posteriorly upward parallel with the spine. I found there was fusion of the eighth, ninth, and tenth ribs, and that this union was extremely dense so that no ordinary forceps would cut through the bone and I had to employ long laminectomy forceps and even a chisel before I could remove this great plaque of bony chest wall in order to make proper exposure. About five inches of the next rib above were also removed subperiosteally. With the finger I was now able to explore the two main chambers of the empyema and turn them into one. Free pleura was not

entered. I found a hollow about the size of an orange, its lower portion resting upon the diaphragm. Upon the diaphragm running forward from a point well anterior to the thoracic opening I found a piece of old drainage tube about 14 French in caliber and four inches long. The rubber had become hardened and brittle, and there was probably some calcareous deposit within. Its presence had never been disclosed in spite of the many roentgenologic examinations. The lung above and anterior looked healthy. I packed the entire cavity with iodoformized gauze and refrained from suturing the wound.

After the first reaction, progress was steady but very slow. A few fine bronchial openings became evident during the healing. In spite of voluntary cough and straining the lung refused to come to the surface and I had to wait until I became impatient and on July 27, 1933, more than two months after my first procedure, I operated again, this time using nitrous oxide and oxygen anesthesia. I did not interfere with the deep part of the wound which looked perfectly healthy but merely incised along the entire length of the opening, undermining the skin and subcutaneous tissues until the edges could be brought together without tension. While the wound was wide open, I found in the anterior part of the lung among the granulations a small bronchial fistula. I painted its lining with 35 per cent silver nitrate* which produced instant cough reflex, but this ceased in a few seconds.

A small piece of bare bone was found and removed and a rib anteriorly was resected so as to drain nearer to the limits of the cavity. Upholsterer's stitches of silkworm gut were put in and other sutures more nearly approximated the edges of the wound.

The wound healed nicely except the drainage opening which I had left which discharged a small quantity, and I supposed that the bronchial fistula was still open though it must have been a small one.

Cough now became annoying but on careful examination no evidence of tuberculosis was found, and indeed the patient improved greatly in nutrition and felt himself well except for the cough and the expectoration which for some weeks had contained dark blood. There was no fever and in order to obliterate the cavity in the chest I laid a thick pad of gauze upon the moving area of the chest wall and held it in place with elastic adhesive plaster, known as elastikon, applied so as not to impede the motion of the opposite hemithorax.

The wound finally healed and the patient was sent home, but there was still a limited flapping area of chest wall. A few weeks later there was a spontaneous opening from which a very small quantity of blood was discharged and with corresponding diminution of sputum. In order to collapse the movable area of chest wall, which was about 2.5 inches in diameter, I had a spring truss made and applied in such a way that the pad of the truss made pressure over this movable area while the spring of the truss surrounded the patient's body but did not touch the skin of the opposite chest.

In discussing the matter of foreign bodies in the chest with Dr. C. B. Rabin, he made the thoroughly practical suggestion that nothing transparent or nonabsorbable should be used within the chest. It then occurred to me that it should be the practice never to use a transparent tube or other apparatus within the thorax even with all the mechanical precautions which are usually followed. I shall take this matter up with the rubber manufacturers who should not find it difficult to incorporate opaque material in the walls of even the softest rubber drainage tube. It is my hope that with this precaution any tube or other substance used as a drain or plug within the thorax will be easy to discover by roentgenology.

*W. E. Adams and H. M. Livingstone, Lobectomy and Pneumectomy in Dogs, Arch. Surg., November, 1932, page 898.

A New Application of the Principle of Suction Irrigation in the Treatment of Empyema Thoracis. MILTON SILLS LLOYD, M.D.

The following presentation is not intended to be a study of empyema thoracis and its treatment. Neither is it intended to be a criticism of any of the methods at present in vogue for the treatment of this condition. My object is simply to place before the profession a method which I have used with success during the last two years. No statistics are presented because insufficient numbers of patients have been treated to warrant the issuance of generalized claims.

Disregarding the pathogenesis of empyema as applied to its treatment, let us begin with the conclusion that there are certain well-defined principles which must be observed if success is to be anticipated. These may be divided into the desirable and the undesirable elements, of which there are three on either side. They may be cited as follows:

A. Objectives to be attained:
   1. Nutrition of the patient.
   2. Drainage, as complete and early as possible.
   3. Expansion of the lung.

B. Features to be excluded:
   1. Operative shock.
   2. Flutter of the mediastinum.
   3. Chronicity (pleural dead space—unexpanded lung).

Having now laid down these principles let us see by what means they can best be satisfied. The question of nutrition is most important in children. It frequently happens that the changing of dressings, changing of drainage tubes, changing of irrigating fluid, and sometimes even the changing of doctors induces in the patient such a state of apprehension that the mere appearance of any one concerned with his postoperative care is an apparition fit to induce nausea and vomiting. Consequently the greater the degree of freedom from postoperative manipulation, allowed by any method, the more desirable is the method.

In respect to drainage and flutter of the mediastinum, no emphasis need be made to any one with experience in this field of the difficulty, under the old principles, of deciding on "the proper time" to drain, of securing adequate drainage at the "lowest point" and of avoiding dyspnea, collapse, and even sudden death when an open pneumothorax (especially in children) is induced at the time of operation. The solution for these problems has been worked out by Harloe and others, in a very satisfactory way, by the perfection of closed drainage methods. As a by-product of this system the elimination of operative shock should also be mentioned. By blocking off, near the spinal column, the nerve lying in the interspace selected for the drainage site, or better still, this nerve together with the one immediately above it and the one immediately below it, followed by local infiltration, the whole procedure may be completed without the patient's awareness of the fact, except for the first hypodermic needle.

It is physiologically recognized that every body cell contains an enzyme (autolysin) capable of digesting it. This enzyme is active only in an acid medium. The cytoplasm changes gradually from alkali to acid in reaction after the death of the cell. These cells, then, partially digested, are entangled in the meshes of an accumulating network of fibrin and form a mass of toxic débris, against which the pleura thickens itself by inflammatory and fibrous tissue formation to prevent absorption. If these substances (pus cells and fibrin) are carried off as rapidly as they form, the pleura

is relieved of this extra burden. Its reaction is rapidly changed from a defensive to an offensive one. The enzymes are free to tear down and remove its battered ramparts. The thickness of the pleura is quickly decreased, its flexibility increased and the lung is capable of an easy and rapid expansion.

Even in chronic cases this is true to a certain degree, and a surprising reduction in the thickness of the pleura appears to be attainable by keeping the "dead space" constantly clean. After the pleura is thinned down and a clean granulating surface is exposed, the approximated peripheral layers begin to come into closer relation as a result of fibrous tissue union and cicatricial contraction. If this process goes

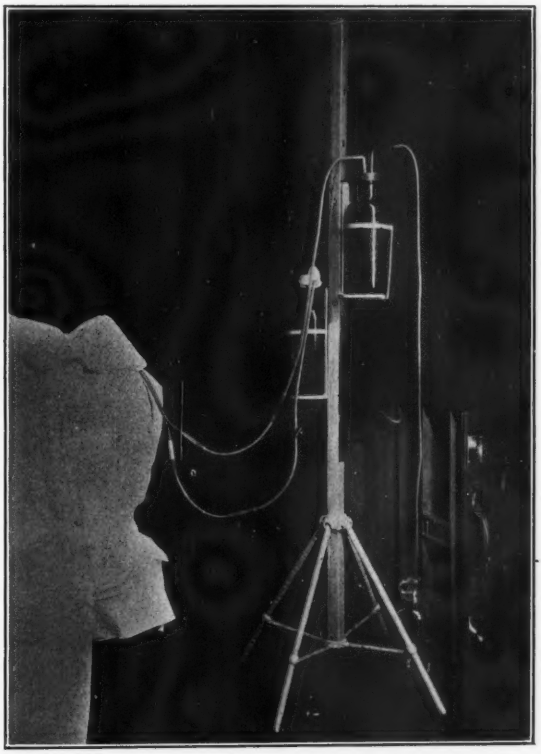

Fig. 1.—Specially designed carrying case and collapsible equipment for the treatment of empyema thoracis by the author's method. The two-way catheter is also shown. The level of the bottles in this illustration is as used at the time of the insertion of the catheter for the initiation of drainage.

on to its natural conclusion, the empyema is cured. This desirable end, however, is impeded by the natural tendency of the lung to collapse and quit the chest wall and by the difficulty in pulling out a rigid, chronically thickened pleura. In the latter instance the pleural surfaces must be approximated by some kind of mechanical assistance. Either the chest wall must be carried down upon the lung, or the lung must be pulled out to the chest wall. The first maneuver requires thoracoplasty; the second requires the maintenance of a constant negative pressure within the chest cavity.

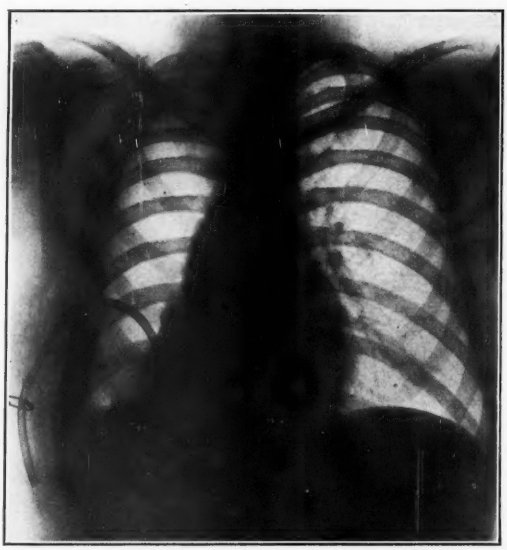

Fig. 2.—X-ray photograph of a patient five months after an attack of pneumonia (left side) and one month after open drainage of an empyema. The persistent collapse of the left lung is no doubt due to the fact that the empyema existed for some time before the patient sought the advice of his physician. Note also the extent of pneumothorax below the level of the drainage tube.

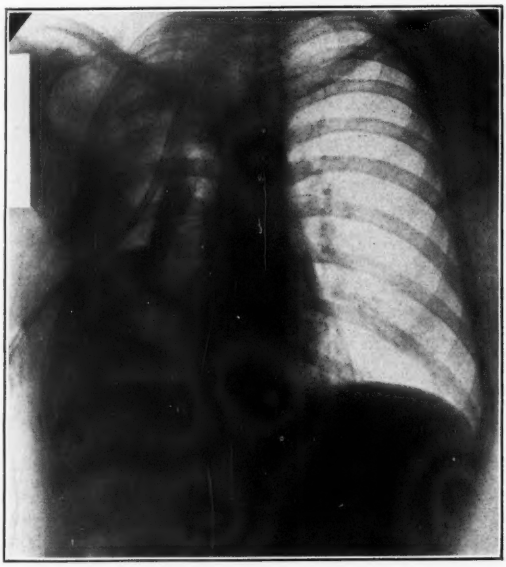

Fig. 3.—Same patient as shown in Fig. 2, three and a half months later and two weeks after the beginning of treatment by suction irrigation. Note almost complete reexpansion of the lung. Contact below the thoracotomy wound gives drainage from the lowest point. The shifting of the trachea, heart, and diaphragm into the left hemithorax is evidence of the effectiveness of the constantly maintained negative pressure. Two weeks later x-ray pictures showed the lung completely reexpanded and the empyema cured.

We may conclude therefore from these considerations, that the principles laid down in paragraph two are best satisfied by early drainage under closed precautions followed by constant removal of pus under constant negative pressure.

The apparatus described below is designed to meet these requirements with the additional necessity of an irrigating fluid as a vehicle for the removal of the pus. (Fig. 1.)

A vertical standard about six feet high is made to support two gallon bottles, one on either side. These bottles are independently adjustable upward and downward between the levels of three feet and six feet. One bottle is stoppered by an air-tight cork and forms part of a siphon system with a bucket placed below it on the floor. The negative pressure thus created by this system is controlled by a piece of rubber tubing about four feet long provided with a screw pinch cock. The second bottle contains a portion of glass tubing, long enough to reach the bottom, the free end of which is connected with a piece of rubber tubing about four feet long, provided with a screw pinch cock. When in use this bottle contains sterile irrigating solution. The bottle, therefore, and all tubing connected with it must be boiled before setting up, and during operation the neck of the bottle should be protected by a loose plug of sterile gauze.

The essential difference between this system and any of the many other negative pressure methods which have been devised, is that a two-way catheter (Fig. 4) must

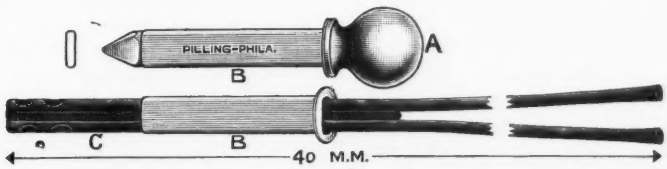

Fig. 4.—Bethune oblong trocar and cannula and specially designed 18 F two-way catheter. After insertion through the intercostal space, the trocar *A* is withdrawn and the catheter *C* is inserted through the cannula *B* as illustrated.

be inserted into the chest cavity. This may be done according to the method of Harloe,[1] in the patient's bed, by inserting a trocar (Fig. 4) of suitable size under local anesthesia and passing the catheter through it. If the surgeon prefers, he may make a small incision over the site of election and cut down as far as the pleura. The pleura is then perforated by a blunt hemostat and the opening enlarged by spreading the blades. The catheter may then be inserted without a trocar. If the latter procedure is chosen, it is apparent that absolutely air-tight precautions cannot be observed. It will presently be apparent also, that the admission of from 20 c.c. to 30 c.c. of air into the chest cavity is of no consequence. The operator should remember that the incision must be small enough to make air-tight contact with the catheter after it is inserted. The siphon bottle is placed at a level of about four feet from the floor, and the irrigating bottle is so placed that its fluid level is about six inches below the patient's chest. The tubes from the two bottles are then connected by means of glass irrigating tips with the two branches of the catheter. Both stopcocks are released. The pus is then drawn slowly from the patient's chest by the siphon system until a partial vacuum is established within the pleural cavity. Irrigating fluid is then sucked in from the second bottle and the completed circulation begins. In the majority of cases all pus can be removed in from fifteen to twenty minutes. The rate of flow may then be regulated by means of the pinch cock on the ingoing tube. If the negative pressure is too high, it may be decreased by raising the drainage bucket. The system is then allowed to operate con-

tinuously day and night. In the absence of difficulties, such as the plugging of the tubes by clots, etc., the only attention which the apparatus needs is the replenishment of the irrigating fluid and the emptying of the drainage bucket.

Chronic cases where the pleura is very thick may be treated in the same way. The two-way catheter is simply inserted into the already existing sinus. As a rule, however, a higher negative pressure is required, and this is obtained by elevating the patient's bed. One or two feet will generally suffice, although I have used on one particularly stubborn case an elevation of six feet.

The nature of the irrigating fluid to be used naturally demands consideration. After trying several preparations including Dakin's solution and gentian violet, I feel that the best results with the least danger are obtained by the employment of sterile normal saline.

If the apparatus is kept functioning properly, one may anticipate a fall of temperature to normal within the first twenty-four hours, and under ordinary circumstances there is no subsequent rise. By the end of the second day, the return flow carries nothing but flakes of white, partially digested slough from the pleural surface. The output of this material may be measured by emptying the siphon bottle and estimating the accumulation over a period of twenty-four hours. The quantity rapidly decreases, and in the acute cases from ten to fourteen days suffice to obtain an almost completely clear return flow. At this point the empyema may be considered cured, and the apparatus may be removed. It is perhaps advisable to leave a small piece of rubber tubing or rubber dam in the mouth of the sinus to maintain its patency until healing from the inside has been completed. There should, however, be no further accumulation of pus and no irrigations are needed. In chronic cases the same result may be expected in from fifteen to twenty days.

A further advantage of this method is seen in the fact that the negative pressure brings the lung into contact with the chest wall below the point of drainage, provided that the tubes are directed upward. Consequently, when the apparatus is removed, the remaining space is always drained from the lowest point, regardless of the relation of the sinus to the lower level of the original pus pocket. Certain authors claim that drainage will continue, as long as a foreign body is left in an empyema sinus. Experience with this method fails to substantiate this claim. On the contrary, it has been frequently observed that the sinus will close so completely and tightly around a small remnant of drainage tube that considerable force must be used to pull it out. The truth is probably the same in reference to these foreign bodies as it would be in reference to this type of foreign body anywhere else in the body. In the presence of an uncontrolled infection, they promote and prolong suppuration, but in the presence of a controlled infection or in a sterile field they are quickly encapsulated by fibrous and granulation tissue in an effort to exclude or extrude them from the organism.

Naturally the above remarks do not apply to the treatment of tuberculous or "mixed infection" empyemas, where the expansion of the lung may be contraindicated on account of the coexistence of a tuberculous lesion within the parenchymal tissue. In the pyogenic types, however, reexpansion of the lung improves drainage, shortens the residence of chronic inflammatory processes and decreases the danger of such disagreeable sequelae as bronchiectases.

CONCLUSIONS

1. A method of treating empyema thoracis is presented, which, in the opinion of the author, gives the quickest and safest restoration of the altered physiologic and anatomic state to normal.

2. Operative shock and mediastinal flutter are eliminated.

3. Holding the lung out against the chest wall by negative pressure during treatment is an insurance for the patient against "dead space" in the pleural cavity (chronic empyema).

4. Follow-up treatment is simplified, because the pleura is thin, the pleural space is reduced to a minimum and is clean, and drainage is always from the lowest point. (Figs. 2 and 3.)

5. Experience would indicate that the average length of time necessary to cure the acute type of empyema, regardless of the infecting agent, should be from ten to fourteen days. The chronic type of empyema also responds satisfactorily but the time required for treatment is longer, probably from fifteen to twenty days.

6. Most cases of chronic empyema may be cured by the faithful application of the principles described without any operative procedure whatever; whereas previously there was practically no hope for such cases apart from thoracoplasty.

This equipment is being made by the George P. Pilling & Son Co., of Philadelphia. A specially designed trocar and cannula and a two-way catheter, each calibrated in centimeters, are illustrated in Fig. 4.

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1. Harloe, Ralph F.: J. A. M. A. 73: 1874, 1919.

Department of Reviews and Abstracts

Conducted by Duff S. Allen, M.D., Associate Editor

Selected Abstracts

Sundberg, C. G.: The Roentgen Kymogram of the Normal Heart. Acta radiol. **14**: 558, 1933.

The author modifies Stumpf's surface kymograph in that several parallel slits of metal through which the roentgen rays might pass are employed. The apparatus is so arranged that the speed of the film-cassette may record 2 or 3 pulsations. The rate of the film is 15 to 20 mm. per second. One whole heart cycle is recorded, therefore, on 10 to 15 mm. of film. This permits of study of the displacements of the heart outlines in the various portions of the heart. Movements which last more than 0.01 second can be recorded. Electrocardiograms taken simultaneously with the roentgen kymogram aid in the interpretation of the records.

Experiments are recorded in which the movements of the heart were studied in dogs first by the injection of lipiodol into the pericardium and later by sewing small pieces of lead to the outside of the walls of the heart. The apex of the heart moves but little as compared to the movements of the auriculoventricular border. The lateral borders of the heart in the dog during systole are displaced more than the anterior and posterior surfaces. It is possible to measure the changes in size of the auriculoventricular orifices.

The method may lend itself to a study of the movements of foreign bodies in the heart or to a study of the movements of calcified foci in the heart.

Roentgen kymograms were taken from the right ventricle, from the left ventricle, and from the right and left auricles and the aorta. A detailed consideration of the significance of the normal movements of the auricles, ventricles, and the aorta is given. From this study of the normal movements of the various chambers of the heart it appears that such a study of pathologic cases may give additional information.

The subject of roentgen kymography is further discussed in the same journal (p. 652) by Bengt Ihre. He finds that the roentgen

kymograph permits of study and diagnosis of pleuropericardial lesions and pericarditis. In the differential diagnosis between mediastinal tumors and aneurysm it is sometimes the only method by which the correct diagnosis could be made.

J. Friman-Dahl in this series of discussions (p. 653) used the roentgen kymographic tracings to study flutter arrhythmia and pulsus trigeminus as well as auricular fibrillation. These arrhythmias are recorded better, however, by means of the electrocardiograph.

Goodall, H. W., and Hoyt, L. H.: Thoracic Stomach. Arch. Int. Med. **53**: 594, 1934.

The authors distinguish between hernia of the diaphragm and "thoracic stomach." In the latter condition the esophagus is shorter than the normal, and a part or all of the stomach lies within the thoracic cavity as the result of maldevelopment of the embryo—Brun Masselot and Jaubert de Beaujean reported one case of "nondescent of the stomach with inversion, the movement of rotation around the vertical axis being toward the right instead of to the left." Lewald differentiated between thoracic stomach, eventration and hernia of the diaphragm.

Five cases of thoracic stomach are reported here in detail. In four of the five cases clinical diagnoses were made before roentgen ray studies. Dyspnea, especially marked after eating, was a frequent complaint. Hyperacidity is frequent. Substernal oppression after eating is also a frequent symptom. In three of these five cases the greater part of the stomach was above the diaphragm.

The embryologic development of the esophagus, diaphragm, and stomach is reviewed in the differentiation of thoracic stomach from hernia of the diaphragm. In true diaphragmatic hernia, the esophagus passes through the esophageal hiatus of the diaphragm normally, and the fundus of the stomach herniates. In these cases of thoracic stomach the esophagus is shorter than normal and ends above the diaphragm.

Freeman, E. B.: Chronic Pericardial Effusion in Myxedema. Ann. Int. Med. **7**: 1070, 1934.

Freeman comments on the dearth of publications dealing with the effect of myxedema upon the heart. Zondek has described the myxedema heart as having (1) enlargement, (2) feeble heart action, (3) slow rate, (4) low P and T-waves in the electrocardiogram. These changes have been explained as being due to edema of the heart muscle, diffuse dilatation of the heart, edema of the tissues surrounding the heart, and to effusion into the pericardium.

A patient is reported who complained of shortness of breath, weakness and cough. The eyelids were edematous. There was unusual

sensitiveness to cold. Examination revealed enlargement of the heart to the right and to the left. The skin was dry. There was pitting edema of the ankles. Fluoroscopic examination of the heart showed absence of pulsation in the cardiac shadow. The electrocardiograph showed no T-waves, and the QRS complexes were low. The basal metabolic rate was minus 45, i.e., 55 per cent of the normal expected rate.

Four hundred and twenty-five c.c. of clear straw-colored fluid were removed from the pericardium. Two weeks later 800 c.c. were removed.

Thyroid extract was administered, and following this the signs of myxedema disappeared. At the same time the fluid disappeared from the pericardial sac and had not reaccumulated at the end of two and one-half years, during which time thyroid extract had been administered continuously. The basal metabolic rate had been held near the normal during this time.

Book Review

PULMONARY TUBERCULOSIS: MEDICAL AND SURGICAL TREATMENT. By H. Morriston Davies, M.A., M.D., M.Ch. (Cantab.), F.R.C.S. (Eng.), Medical Superintendent, Vale of Clwyd Sanatorium; Consulting Surgeon to University College Hospital, City of London Hospital for Diseases of the Heart and Lungs, King Edward VII Welsh National Memorial Association, Lancashire County Sanatorium, Cheshire Joint Sanatorium. With chapters on Tuberculosis in Childhood by W. Burton Wood, M.A., M.D., (Cantab.), M.R.C.P. (Lond.), and on Specific Treatment by L. S. T. Burrell, M.A., M.D. (Cantab.), F.R.C.P. (Lond.). Pp. 464, with 69 text figures and 77 radiographic plates. London, Cassell and Company, Ltd., La Belle Sauvage, E.C. 4.

The name of Morriston Davies in the minds of all in this continent who are interested in thoracic surgery is perhaps better known than that of any other in the British Isles. Beginning his professional career as a surgeon at the University College Hospital, in London, he later gave himself entirely to the study of thoracic diseases, and more and more made the Vale of Clwyd Sanatorium, in Wales, his headquarters. He was, we believe, the first, after Brauer, to combine the offices of physician and surgeon in the practice of this specialty, and his published work has always given evidence of that beneficent union. In the development of the surgery of pulmonary tuberculosis in particular, his experience, which has now found most excellent expression in the forelying book, has been acquired through exceptional opportunity, and has ripened through close and continual study. He has always built his surgical therapy upon the solid foundation of an intimate knowledge of the pathology of the disease and its clinical course under sanatorium treatment; and that is why the writer particularly welcomes Mr. Davies's book as a real achievement. There are many surgeons in America, in Canada, and in the Old Country, whose interest and whose ambition alike have been greatly stimulated by the opening up during the last generation of this new field of surgery, and who desire a reliable guide in their studies. To all such one can confidently recommend this book.

It is impossible, of course, in the space at one's disposal, to give any complete idea of its contents. A good half of the book is devoted to a consideration of the pathologic and medical aspects of pulmonary tuberculosis, and the surgeon will do well to study this part quite as closely as the second half, which deals with the therapy of collapse. Mr. Davies rightly makes it clear that any one who proposes to operate on a tuber-

culous patient ought first to know the disease tuberculosis. Teamwork here is, of course, essential for most of us; but the surgeon must be able to keep pace with his medical colleague.

Twelve chapters are devoted to this part of the subject, occupying two hundred and nine pages. They represent a succinct but thorough statement of present-day knowledge concerning the modes of infection, symptomatology, physical signs, diagnosis, sanatorium and general treatment, special treatment, and complications. Dr. Burrell, of the Brompton Hospital, contributes an excellent though short chapter on special treatment, including tuberculin, sanocrysin, light treatment, inhalations, vaccines, and shock therapy. Dr. Burton Wood writes the chapter on tuberculosis in childhood. This part of the work is thoroughly practical and is well illustrated.

The second half of the book deals with the mechanical treatment of pulmonary tuberculosis, under the general heading of collapse therapy. It begins with a chapter on artificial pneumothorax and its complications, which, though short (occupying some sixty pages), gives one all the essentials, and is well up to date.

There follows an excellent chapter on the surgical treatment of adhesions, restraining the effect of a pneumothorax, and the author discusses authoritatively the operation of Jacobaeus and its modifications. He declares himself in favor of the use of separate cannulae for thoracoscope and cautery, as opposed to Chandler's single thoracoscope. He believes in the use of the coagulating high-frequency electrode as a protection against hemorrhage, followed by the galvanocautery for cutting, rather than the high-frequency cutting knife.

The subject of oleothorax is treated at some length. Mr. Davies is rather in favor of it, and uses gomenol, but he does not fail to indicate the dangers inherent in its noncompressible character. We generally think of the French school as strongly supporting oleothorax, but it is perhaps not widely known that there exists also a strong French opposition to its use, notably on the part of Sergent, who claims that lung perforation is a common complication of oleothorax. For our part, we believe that a disinfection oleothorax, for cases of empyema, is of value only when the empyema is a mild and purely tuberculous one, and that a compression oleothorax is often with advantage substituted by a thoracoplasty.

The chapter on phrenicectomy is to be commended for its sound conservative point of view. The author lays down quite definite indications, which, on the whole, are decidedly more restricted than has come to be the practice in this continent, and, in the reviewer's opinion, rightly so. A crying need of the moment in this country is for greater precision and greater clinical reasonableness in the indications for this operation. There is a tendency to run wild over it, and Mr. Davies's chapter is to be commended.

The chapter on thoracoplasty, which, after all, constitutes the major part of the surgical treatment of pulmonary tuberculosis, occupies a little less than sixty pages, which is perhaps too short for a book of this character. It is to be hoped that in succeeding editions Mr. Davies, out of his abundant experience, will give us a fuller discussion. There is no doubt that what he does give us is sound stuff; although in the time that has elapsed since the publication of the volume, several modifications of the operation have been proposed which are fundamental in nature and compel a fresh discussion of procedures which were previously accepted as standard. Mr. Davies follows Sauerbruch in still recommending a one-stage ten- or eleven-rib thoracoplasty for favorable cases, although admitting that the operative mortality is higher than with the two-stage or multiple stage operation. The tendency on this side of the water has set very strongly in the direction of the three- or even four-stage operation, following in this respect the lead of O'Brien, who says "never more than three ribs at one time." After all, the operative mortality is the most important thing; more so than completeness of collapse. A living patient with a residual cavity is always better than a dead one with a complete collapse. But this divergence in practice is, after all, not so striking as at first it appears. Mr. Davies adheres to the practice of Sauerbruch in resecting only a comparatively short length of rib, from 3 cm. up to 12 cm. (Sauerbruch advises resecting only from 4 to 8 cm.) The amount of collapse secured is correspondingly limited but the danger of mediastinal flapping is also decreased. In this continent, on the other hand, the general tendency is to remove a longer portion of rib, and consequently one has to avoid the danger of mediastinal flapping by dividing the operation into two or more stages. However, one should not omit to say that for the large or thick-walled apical cavities Mr. Davies does accept a two-stage operation, and then removes a larger portion of the upper five ribs, taking 6 cm. from the first, 10 cm. from the second, and 15 cm. from the third, fourth and fifth at the first stage, and shortening the portion removed for the second or lower stage thoracoplasty. But this still stops short of O'Brien's principle of complete removal of the upper three ribs in such cases, and it has to be expected that O'Brien's operation will improve results in the direction both of lowered mortality and of greater collapse.

It is to be feared that we have already overstepped the limits of a book review. But there are so many points for discussion in this subject (so live a one today), that it is a great temptation to write at length.

Let us conclude by mentioning that the final chapters on extrapleural pneumolysis, or plombage, on intercostal neurectomy, and scalenectomy (credit being given to Fisher), and on various other smaller procedures, are all excellent. The final chapter in the book, upon the sanatorium of the future, is interesting. In it Mr. Davies expresses himself in favor of the establishment of a certain number of central sanatoria of from

250 to 300 beds, fully equipped and staffed for all medical, surgical and nursing requirements, and situated within reasonable distance of a center from which the various consultants could be drawn. It would still be necessary to maintain smaller sanatoria, but the cases for surgical treatment would be transferred from these to the larger hospital-sanatoria. With this opinion we must all agree.

Edward Archibald, M.D.

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The American Association for Thoracic Surgery

The seventeenth annual convention of the American Association for Thoracic Surgery was held in Boston, Mass., May 31, June 1 and 2, 1934. The number of members in attendance at this meeting was larger than that at any previous meeting of the Association since its inception.

This year, again, we were honored by foreign visitors who had been invited to appear on the program. Mr. A. Tudor Edwards of London, England, spoke on "Malignant Disease of the Lungs." Dr. Harold Jessen of Davos-Platz, Switzerland, discussed "Thoracoplasty in Bilateral Cavernous Tuberculosis." In addition to these foreign visitors there were a number of visitors from all parts of the United States and Canada and one visitor each from England and Australia.

The formal program dealt with a variety of topics relating to the surgery and physiology of the thoracic organs. These papers will appear in the JOURNAL OF THORACIC SURGERY. Lobectomy and pneumonectomy for carcinoma of the lung and bronchiectasis were discussed extensively. The indications for the one stage operation and for the multiple stage operation were brought out both in the papers by the various authors and in the discussions on the floor. Thoracoplasty for pulmonary tuberculosis, the anatomy and the clinically significant irregularities of the diaphragm were dealt with. Papers on bilateral pneumothorax and bilateral partial thoracoplasty for bilateral tuberculosis, scaleniotomy and phrenicectomy were presented. Various experimental studies were reported.

Besides the formal program, two full half days were given over to demonstrations of research problems under investigation in the various laboratories of the Harvard Medical School and the local clinics and hospitals.

The following officers were elected:

President	Dr. John L. Alexander	Ann Arbor, Mich.
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The following associate members were advanced to active membership:

Dr. W. P. Herbert	Asheville, N. C.
Dr. Richard H. Meade, Jr.	Philadelphia, Pa.
Dr. Harlan Newton	Boston, Mass.

The following were elected to associate membership:

Dr. Maurice Berck	New York City.
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Dr. Louis Davidson	New York City.
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Erratum

In Dr. E. J. O'Brien's article, "The Present Status of Thorocoplasty," in the December, 1933, issue of the Journal, p. 163, in the last paragraph the sentence beginning on the fourth line from the bottom should read:

"In the remaining 51, there were 50 who had positive sputum, and 1 who had no material."

Just as this issue goes to press word reaches us of the sudden death of Dr. Carl A. Hedblom. Dr. Hedblom was one of the most active men on the Editorial Board of this Journal. He was a past president of the American Association for Thoracic Surgery and one of its most progressive members. A more suitable and more extensive biographical sketch will be published in a subsequent issue of the Journal.